Construction Methods and Equipment Management
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Lecture-10
Earth Moving Equipment-Bull Dozer

Hello everyone, I welcome you all to the lecture 10 of this course construction methods and equipment management. In this lecture, we are going to discuss about the earthmoving equipments specifically about the bulldozers.

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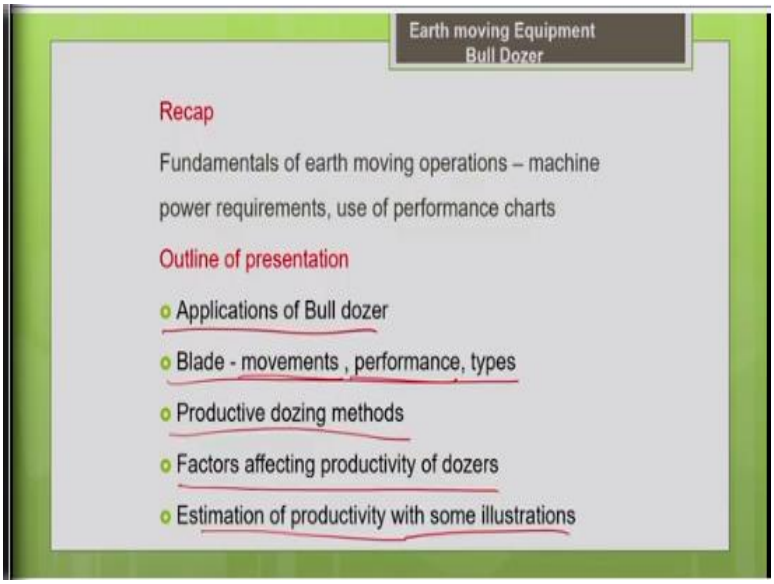

So, in the last lecture, I introduced you to the various fundamental terms related to earthmoving operations, like how to determine the power requirements of the machine and what is the significance of performance chart, how to quantify the payload of the machines? So, all those terminologies related to the earthmoving operations were introduced in the previous lecture.

Now, let us see what is the outline of today's presentation? So, in the today's presentation, we are going to discuss about what are all the applications of the bulldozer. So, there will be some series of lectures on different earthmoving machines. So, in this lecture we are going to discuss about the bulldozer. We will look into what are all the uses of bulldozer and what are all the different types of the earthmoving blade which we use commonly for the bulldozer.

So, what are all the possible blade adjustments and the blade movements with the bulldozer, how to assess the blade performance. Say and what are all the different productive dozing methods which can be adopted to enhance the productivity of the bulldozer. So, the factors which affects the productivity of bulldozer and how to estimate the productivity of the bulldozer with some in illustrations. So, these are the things which are going to discuss in the upcoming slides.

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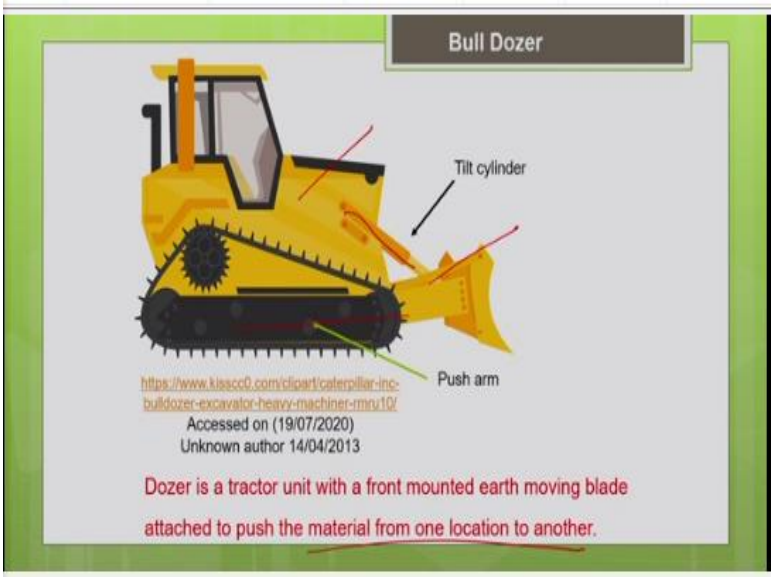

So, most of you might have seen the bulldozer, it is basically a tractor unit connected to your earthmoving blade. So, it is nothing but your tractor unit connected to your blade. So, with the help of this blade, you can push the material from one location to another location. So, you can see that there are possibilities of different types of the connection between this blade and the tractor. So, here you can see a type of connection tilt cylinder and a pusher arm arrangement, so with this you can adjust the blade movement. So, similarly there are also possibilities of different types of connections.

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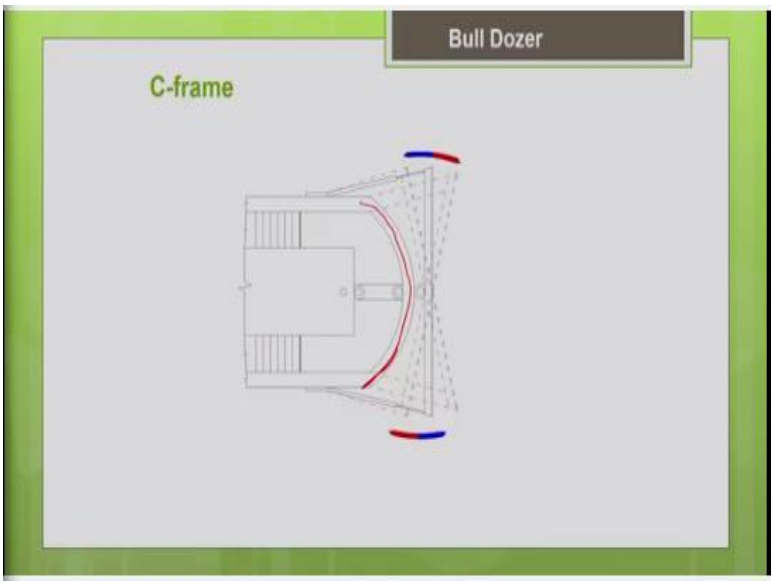

Like say for example, you can have a C frame connection like this, C frame connection between the tractor and the blade. So, with this particular kind of connection, certain types of movements of blade are possible. So, basically the connection between the tractor unit and the blade will decide what are the possible movements or the adjustments for the particular blade. So, we will discuss about the blade movements later.

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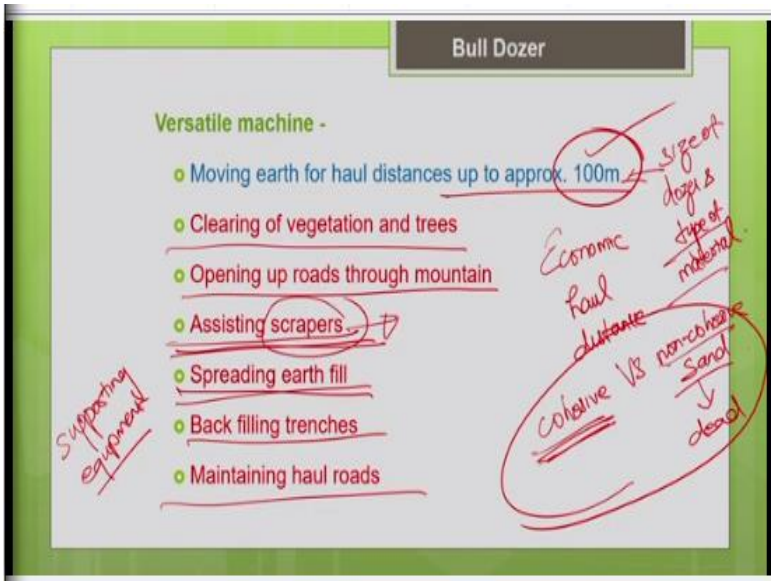

So, this bulldozer is basically a versatile machine. So, it can be used for different types of applications in a construction project site. So, before you select an earthmoving equipment for your particular activity or your particular job, you should know what is the haul distance actually

needed for your actual job, because every earthmoving equipment has it is own economic haul distance**.**

So, every equipment has it is own economic haul distance, this we have discussed earlier also. So, the economic haul distance of a bulldozer, the maximum distance is only 100 meters. So, beyond 100 meter it is not advisable to use this particular machine, you will not get you desired productivity and if you will use it will result in lot of wear and tear for the particular machine**.** So, this machine is designed only for a haul distance of up to 100 meters.

So, the actual distance will design depending upon your size of your machine, your size of your dozer, and the type of the material which you are going to handle, which you are going to push which the bulldozer is going to push. Say if you are going for a bigger tractor, bigger bulldozer, the economic haul distance maybe slightly higher than this. So, the actual distance depends upon the size of the dozer, greater the dozer the economic haul distance will increase.

Similarly, it also depends upon the material which the bulldozer is going to push, say some material are cohesive some material are non cohesive. Say generally the bulldozer can push a cohesive material more easily when compared to non-cohesive material like sand is non-cohesive material. Because a cohesive material can easily roll in front of the blade, so it is easy to push, but your sand it will remain like a dead material, it will not roll easily.

So, the pushing of the sand is little bit difficult with the bulldozer. So, in the case your haul distances get reduced. What is a haul distance possible? Depends upon your size of a bulldozer and it also depends upon the type of the material which you are going to push with the bulldozer. So, commonly you can say the maximum haul distance is up to 100 meters. So, apart from the earthmoving operation, you can use this machine for so many activities.

So, you might have seen bulldozer, used for cutting trees So, it can also be used for clearing the vegetation at the construction site. So, for opening up of roads through mountain, it is a very common supporting machine. So, very commonly it is used as a supporting equipment. Say for

example, for pushing or towing other machines this can be used. Say this scraper; scraper is another earthmoving machine which we are going to discuss in the upcoming lecture.

So, this scraper will also cut the earth, there will be a bowl in the scraper, there will be a blade with the help of the blade you can cut the earth and fill the bowl in the scraper, so this is called as the loading operation. During this particular loading operation, I can take the help of a bulldozer to push the scraper, so that the job of the scraper will be easier. So, that this is used as a supporting machine.

Similarly spreading so you can use the bulldozer for spreading the earth for preparation of your subgrade for your road or whatever for spreading the earth, for filling the trenches for backfilling the trenches, for maintaining the haul roads. So, different applications it is used, that is why we call it as a versatile machine.

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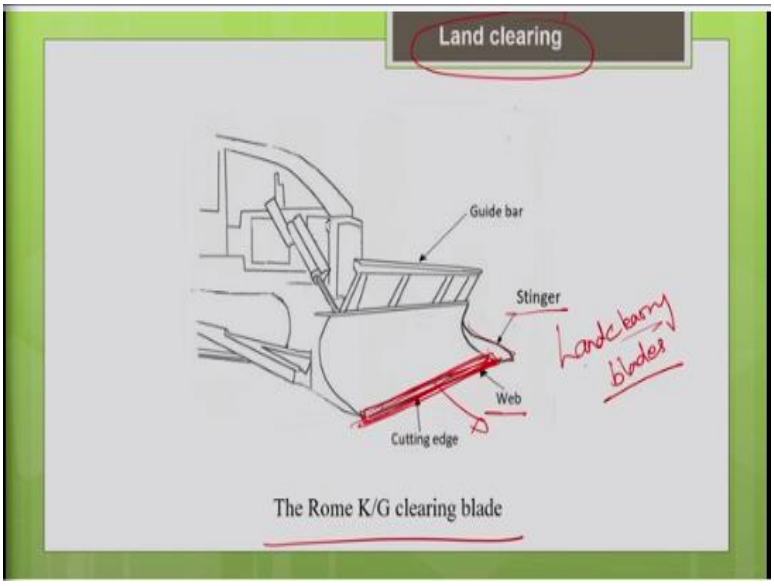

So, let us see some examples. Now you can see this bulldozer can be used for land clearing, so it is used for cutting the trees clearing your site. So, these are special bulldozers, for this purpose, we should not use a earthmoving blade, there are special land clearing blades. One such land clearing blade is Rome K bar G clearing blade, it is a very powerful blade, manufactured by Rome company.

So, this blade you can see it as a vertical knife called as stinger and the horizontal knife called as web. So, it has both the vertical knife and the horizontal knife, so with this, you can easily cut the trees. So, generally for cutting the trees, you need more tractive effort, more power is needed, so you have to use the very big bulldozer. So, you have to choose a very big tractor unit, so that you will be able to deliver more power.

And one more important thing you need to note is there is cutting edge at the bottom of every blade. So, generally when you use the blade frequently, the one which gets worn out very fast is the cutting edge. So, we do not replace blades very often, we replace the cutting edge only. The cutting edge is just bolted; it is just bolted at the bottom of the blade. So, once it gets worn out, you can just replace it with a new cutting edge. So, generally we do not replace blades frequently, but we replace only the cutting edge at the bottom of the blade.

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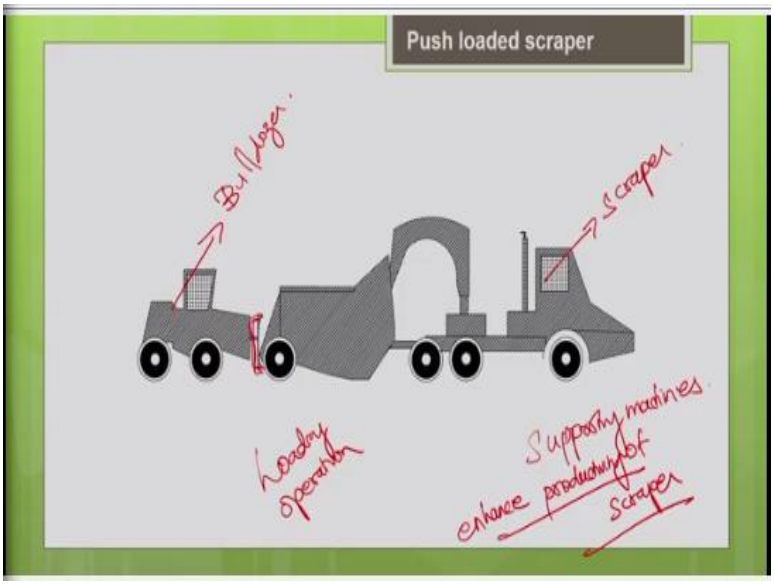

So, this is what I told you earlier, the bulldozer is used for assisting other machines, so it is supporting the other machines. So, this is your bulldozer, so this is a schematic sketch, so the leading one is your scraper. As I told you the scraper has to cut the earth and fill its bowl. So, during that loading operation, your bulldozer will push, you can see it has a special type of blade just for pushing it that blade is called as cushion blade.

I will explain you later when we discuss about the type of blade. So, this bulldozer will push the scraper during the loading operation of the scraper. So, by that process you can enhance the productivity of your scraper. So, this is one application of the bulldozer.

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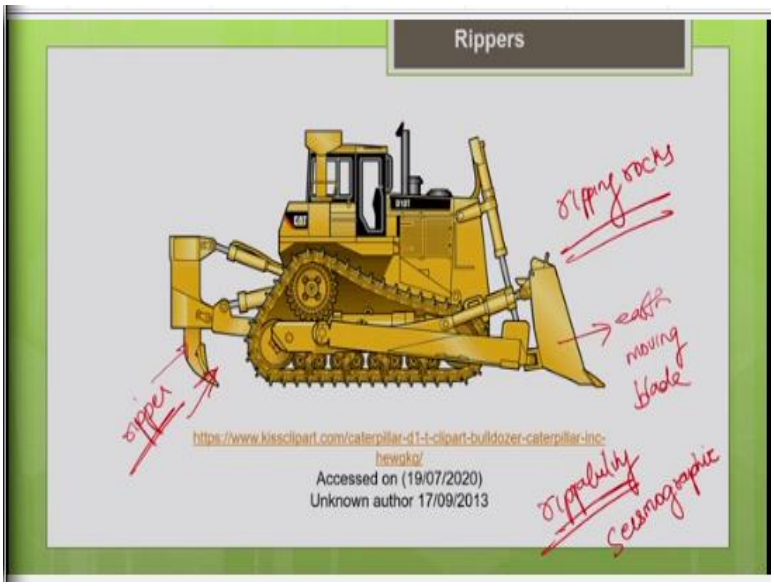

So, other application you can see it can be used as a ripper. So, for this tractor you can see a front end you have this blade earthmoving blade, this is the earthmoving blade, so at the rear end, you have this ripper. So, this is similar to plough what we use in farming. So, basically when we discuss about the earthmoving operations, the steps involved in the moving operations, I told you like the first step is we should loosen the earth before digging it.

So, when you loosen the earth before digging it, the digging becomes easier that will enhance the productivity of the digging job. So, that is my first say for example particularly for the hard terrain, if it is going to be a consolidated clay terrain. In that case first use the ripper, then loosens the earth with the help of the ripper. Once after you loosen it, then use the earthmoving blade and push the earth.

So, we can follow the sequence, so that you can enhance the productivity of the job. Similarly, even before using scraper, scraper is also earthmoving machine. Before using the scraper, I can use a bulldozer with a ripper attachment, loosen the earth first, then use a scraper for loading,

thereby you can enhance the productivity of the scraper. So, this ripper is basically to loosen this material, you can also use this for ripping the rocks, so this can also be used for ripping rocks.

So, you know that the commonly adopted method for excavating the rock is drilling and blasting method, so that is always a costlier method. So, if you are able to use ripper for ripping the rock, you can have a huge saving in the cost. So, first before that you have to check the rippability of rock for that there are some special methods like seismographic methods, we are not going to discuss that in this particular lecture.

There are some seismographic techniques, sound seismographic techniques based upon that you can check whether the rock rippable or not. Once you know that the rock is rippable, you can use this technique for ripping it that will result in huge saving in the cost. Similarly, you can use it also for ripping an old pavement. So, it can have different applications accordingly.

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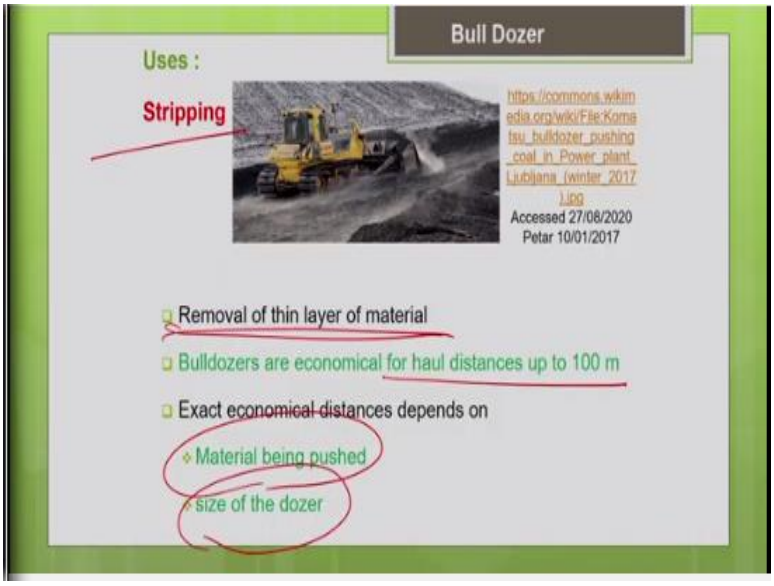

Then stripping, stripping is a very common operation in the construction project site. So, you know that stripping is nothing but removal of the top layer of the soil. So, if the top layer of the soil is weaker one with lot of vegetation, so you have to remove the top layer of the soil. So, depending upon a depth to which the vegetation is available in your soil accordingly you have to remove the top layer, so that is what is stripping.

So, bulldozer you can see very commonly used for stripping the top layer. So, as I told you, the bulldozer is economical only for the haul distance of 100 meters. The actual distance depends upon your size of a dozer and also the material which you are pushing. So, if you are pushing a cohesive material, it is easier for a bulldozer to push, so you can have a little bit greater the haul distance.

But if you are going to push the sand which is non-cohesive, in that case your haul distance is still going to be reduced. It depends upon the type of materials which you are going to encounter in your project site.

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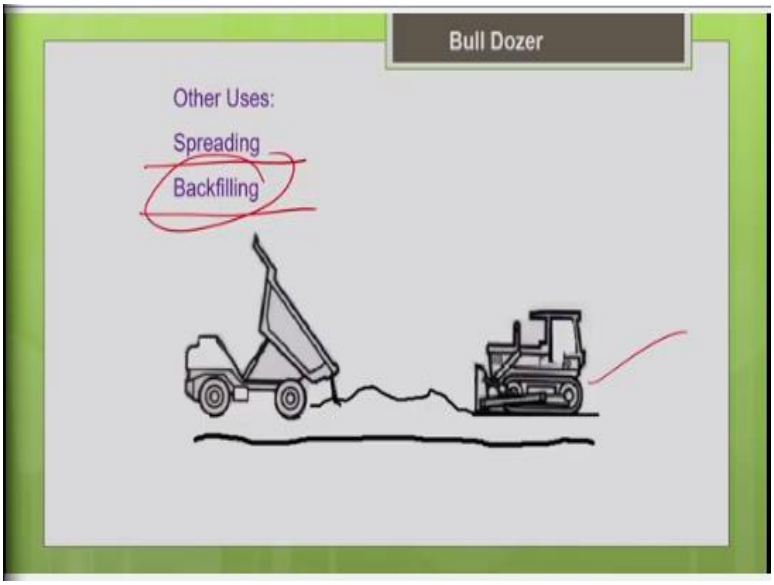

So, what are the other uses? The bulldozer can be used for spreading, backfilling. So, here you can see the example of spreading your truck. Very commonly you can see this in a road construction, the hauling equipment that is a truck, so it will dump the material and your bulldozer is used for uniformly spreading it and it will compact it to the regular thickness, so it helps in spreading the material.

Then backfilling, so when you excavate a trench, say for example, for pipe laying your excavating the trench with the help of the bulldozer, push the material into the trench there is you can backfill the trench. So, there are different applications in a project site.

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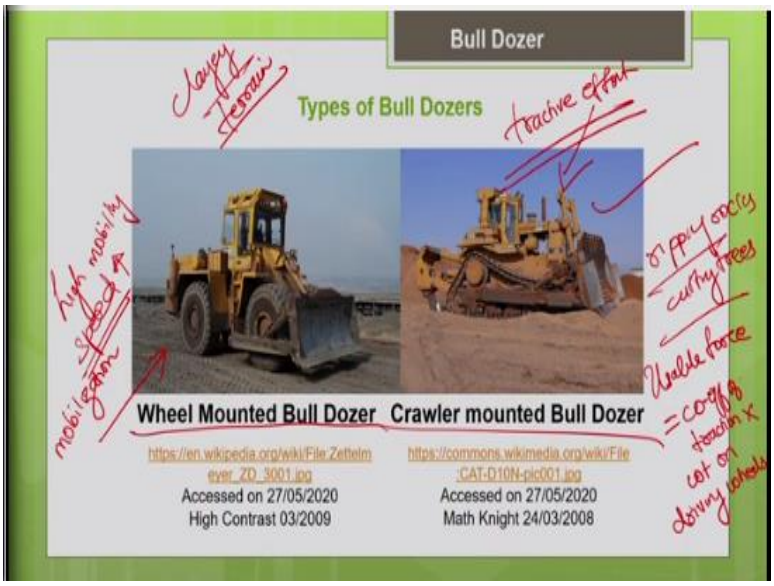

So, now let us look into what are all the different types of bulldozers based upon the mounting. So, there are obviously you know that there are 2 possible mounting one is your wheel mounted bulldozer other one is your crawler. Crawler is nothing but track; you can see the track mounted. So, crawler is nothing but your track mounted, you can see the chain type of track.

So, now let us compare what are the merits and demerits of these both the cases. If you go for wheel mounted bulldozer obviously the main advantage will be it is mobility. So, this one will have very high mobility, this has very high mobility. I mean the speed will be very high with the wheel mounted machines. But with the crawler mounted machine, so there is a restriction on the speed, you will not be able to realize the speed the similar speed what we realized with the tire mounted machines.

Another important thing is you can easily mobilize this machine wheel mounted, mobilization is easier, mobilization to the project site is easier. You can even take it on the highways without damaging the highways to the project site. But in the case of crawler mounted, you need another equipment to mobilize this machine to the project site. So, we cannot use it on the highways, it will damage the highways, so this mobilization is a little bit difficult.

But when you look into the tractive effort**.** So, which one will deliver more power, you know that obviously the crawler mounted will deliver more power, because this track motor has broader

contact area, so the traction develop is more. So, this develops more tractive effort that is why for most of the tough conditions, say for example, ripping the rocks, cutting trees all these are tough jobs.

For that we generally go for only crawler mounted, because that will be able to deliver more tractive effort. We know that already how to estimate the usable force. The usable force is nothing but your coefficient of traction multiplied by weight of driving wheels. Compare 2 cases, 2 different types of bulldozers you have with 2 different mountings, say one is wheel mounted other one is crawler mounted.

Say assumes that both are of same weight, the gross weight of both the machines are same. So, you are going to operate this machine on a clayey terrain. So, obviously which one will have better coefficient of traction? When compared to the tire mounted on a clayey terrain definitely your crawler mounted will have better coefficient of traction. So, there will be proper grip between the track and the haul route.

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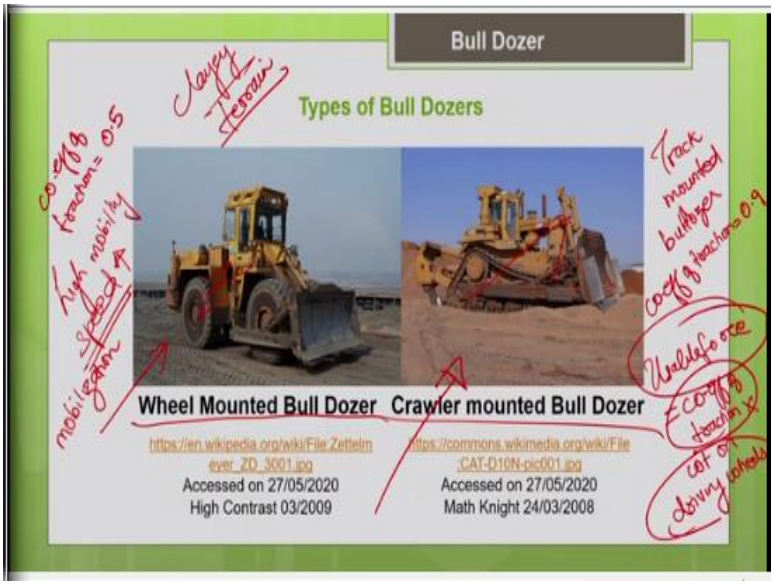

So, what happens if you go for say when you consider your track mounted or crawler mounted bulldozer. Here the coefficient of traction says it may be approximately 0.9 on a clayey terrain. So, here for the wheel mounted the coefficient of traction maybe only say 0.5. So, for the same weight of the machine since the coefficient of traction is very high obviously you can see with the usable

force which is generated by this crawler mounted is going to be very much high when compared to the wheel mounted bulldozer.

So, that is why I told you for very tough job conditions you have to go only for the crawler mounted. And similarly, for poor underfoot conditions as I told you for clayey terrain, muddy terrain or rocky terrain, because in the rocky terrain you cannot use your tyres that will damage your tyres. So, you have to go for this crawler mounted. Similarly, if you want to climb a very steep terrain, it will be more easier to use a crawler mounted machine when compared to wheel mounted machine on steeper slopes. So, all these things you should note it when you are select a machine.

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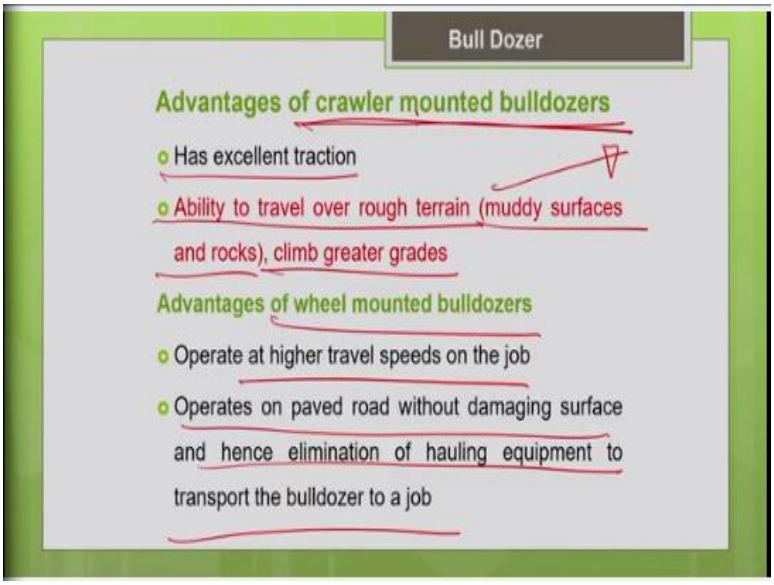

So, let us now summarize what are all advantages of the crawler mounted dozers and wheel mounted dozers. It has excellent traction, crawler mounted has excellent tractions as you know. So, it has the ability to move over rough terrain, your muddy surfaces or rocks or steeper grades everything can be handled by the crawler mounted machines**.** But a wheel mounted machines, the main advantage is it can operate at a high speed and it is mobilization is very easier.

It can be operated on paved road without damaging the surface. Hence there is an elimination of hauling equipment to transport the bulldozer to the job site. So, it can be used on the paved highways and it can be easily mobilized to the project site. But here you need a separate hauling

equipment to carry this crawler mounted bulldozer to the project site, because this crawler track may damage a highway, it cannot be taken on the public highways. So, now, let us look into the blade adjustments.

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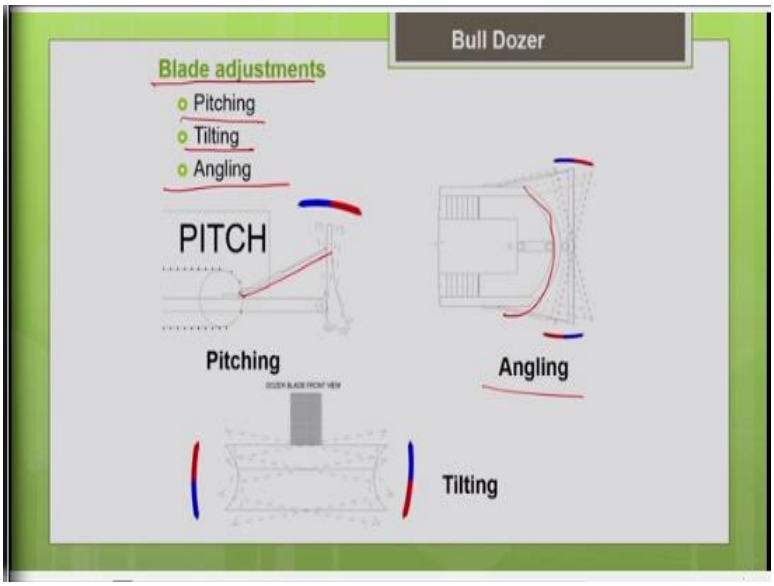

So, what are all the possible blade movements with the bulldozer blade? As I mentioned earlier, the movements which are possible depends upon the connection between the tractor and the bulldozer blade. In some bulldozers you can see this kind of C frame connection between the tractor and the blade. So, those tractors will facilitate certain kind of movements like angling.

Similarly, some of the bulldozers, they have this kind of tilt cylinders and pusher arm arrangement. So, in those bulldozers, some other movements are possible. So, we will discuss what are all the possible movements in detail in the upcoming slides? So, basically pitching, tilting and angling 3 types of the blade movements which are commonly seen in the bulldozer blades.

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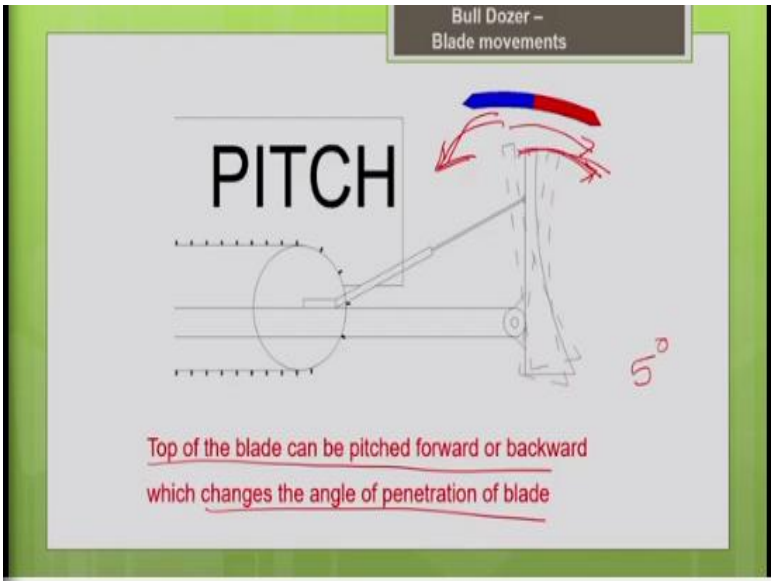

So, what is this pitching? Pitching means, the top of the blade is pitched forward or backward. That means you are moving the top end of the blade either forward or backward. So, this top end of the blade is moved forward or backward. So, why should we move it forward or backward? So, accordingly you can change your angle of cutting, accordingly you can change the depth of penetration of your blade.

Say for example, if you move the blade the top end of the blade forward, it means what happens. So, when you move the top end of the blade forward, it will decrease the penetration of the blade into the soil. So, similarly if we move the top end of the blade backward, it will increase the penetration of the blade into the soil. So, by pitching it forward or backward, either I can increase or decrease the depth of penetration of the blade into the soil.

So, generally when we do the earthmoving operation, you can see that the bulldozer will be cutting the earth for some distance. Once the blade is full after that it will not cut because the blade is already full then you have to just push the loaded earth to the required dumping place that is it. So, when you just want to push the material, so you can reduce the depth of penetration of the blade into the soil.

So, in that case you can pitch the blade forward**,** so that you can reduce the penetration of the blade into the soil, so that is the purpose of pitching. By pitching it forward or backward, so you can

change the angle of attack or the depth of penetration of the blade into the soil. So, how much is the pitch possible for the particular blade is defined by the manufacturer. So, in the specifications given by the manufacturer, you can see say for example, if it may be mentioned 5 degree, so that means the maximum pitch possible with this grade is 5 degree.

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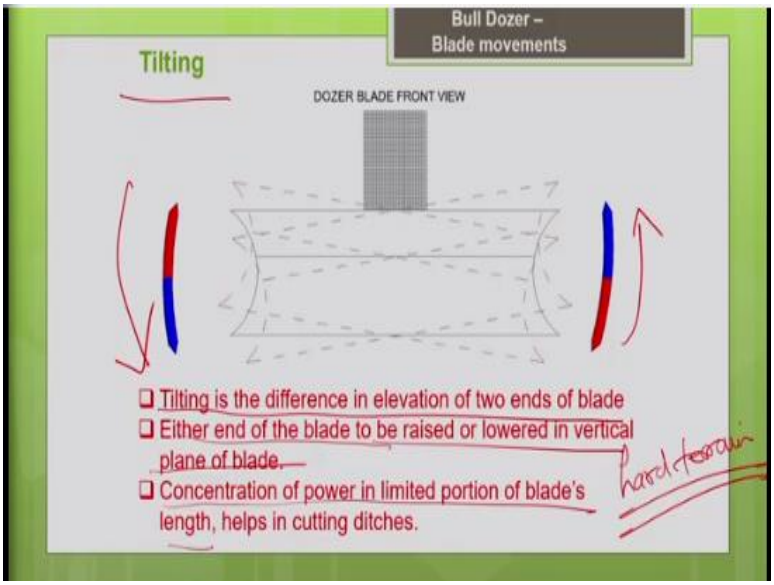

Now coming to tilting, tilting is the next type of movement. So, basically this is a movement in the vertical plane. So, you can raise one end of the blade and lower the other end. So, tilting is a difference in the elevation of the 2 ends of the blades; it is a movement in the vertical plane, why should we tilt the blade?

So, basically when we encounter a tough terrain like very hard soil or consolidated clay, in a very tough terrain, we need more concentration of power. So, if you raise one end of the blade only the remaining portion is in contact with the ground. So, only some portion of the blade is now in contact with the ground. So, the concentration of power will be more in the limited portion of the blade, so it will be very easy to cut the hard terrain.

So, particularly to cut the hard terrain, you have to tilt the blade, so that I can increase the concentration of the power in the available portion of the blade. So, basically either end of the blade is raised or lowered in the vertical plane. The concentration of the power in the limited

portion of the blade's length, it helps him cutting the ditches. So, it helps in the cutting the soil in a very hard terrain.

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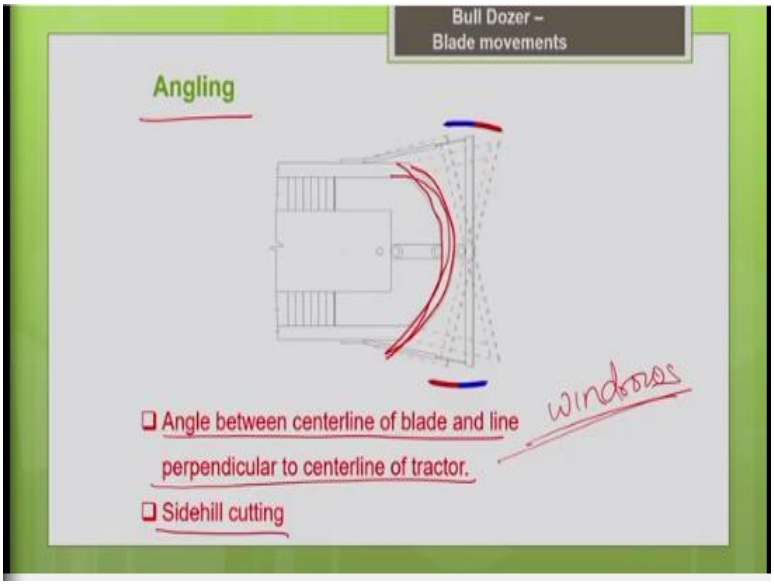

So, next we shall see what is this angling? This angling is possible only if there is a C frame connection between the tractor and the blade. So, basically you can see most of the tractors, the blades are fixed perpendicular to the direction of motion. You cannot angle the blade either to left or to the right in conventional bulldozers what you see. But in some dozers, where you have this kind of C frame connection between the tractor and the blade there is possibility to angle the blade either to the left or to the right, to maximum say 25 degree angle the blade.

Basically, the angle refers to the angle between the centerline of the blade and the line perpendicular to the centerline of the tractor. So, if you are going to work on one side of a road, say for example you are doing some pipe laying, you need to backfill the trench. So, you are working on one side of the road, in that case you can easily angle the blade and backfill the trench.

Similarly, for side hill cutting, and when you are working in narrow constraints, narrow space constraints**.** In that particular places angling will be very easier, so you can just strip the soil and deposit the soil in windrows, windrows of soil. So, using this angle blade it is very easier to do. But basically, angle blade is not considered a highly productive blade with respect to earthmoving

operation, it is not very good in cutting and pushing the earth. I will be discussing that in detail when we discuss about the types of blades.

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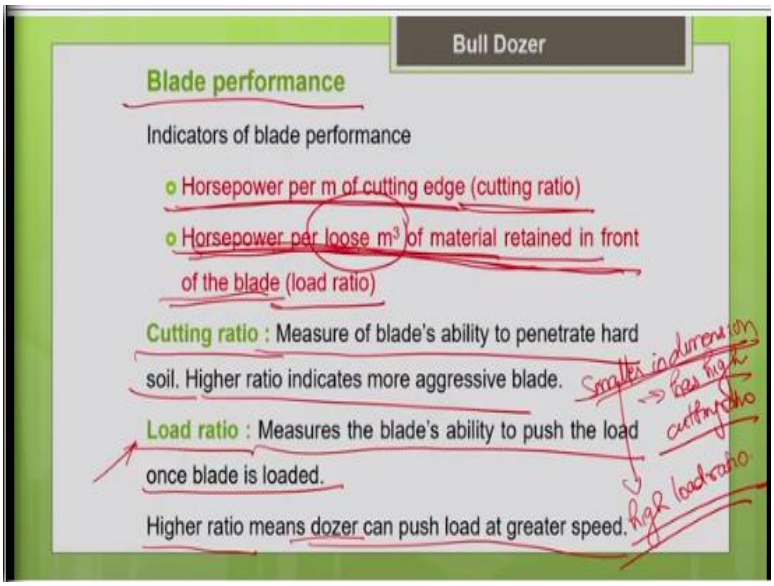

So, we have discussed about the 3 types of movements, one is pitching the other one is tilting and angling. There are different types of blades which we are going to discuss in upcoming slides. You need to note that like for every type of blade, only 2 movements are possible. Either you can go for angling and tilting or you can go for the pitching and tilting. So, these are the 2 options for every blade only to movements are possible.

Blade performance now let us see how to assess the performance of the blade. So, there are some indicators of blade performance. There are some parameters which quantify the performance of the blade. Say, one is cutting ratio, other one is the load ratio, the cutting ratio indicates what is the cutting ability of the blade. So, what is the cutting ability of the blade? I can know it from the cutting ratio.

So, it is defined as horsepower per meter of the cutting edge of the blade. So, first of all we need to know what is cutting edge of the blade. So, generally when we look into the bulldozers I have shown this picture earlier to you.

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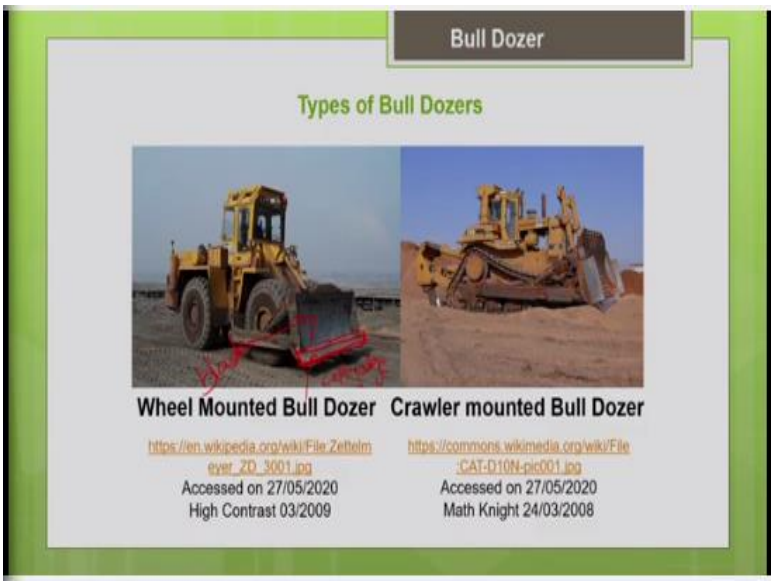

At the bottom of the blade, you can see a plate border. I mean this is the blade at the bottom what you have is the cutting edge; a steel plate is bolted to the bottom portion of the blade that is called as a cutting edge. So, generally this cutting edge gets worn out faster depending upon the usage, you may not replace the blade frequently, you need to replace only the cutting edge frequently.

So, this is easily bolted on to the bottom of the blade. So, we were discussing about the cutting ratio. So, cutting ratio is nothing but horsepower per meter of the cutting edge of the blade. So, that means, it depends upon the concentration of the power in the cutting edge, if the blades are smaller in dimension, then you can see the more horsepower concentration will be there in the smaller blade portion.

So, those blades will be very aggressive, so that can easily cut the earth and move the earth so that can easily cut the earth. So, cutting ratio measures the blades ability to penetrate the hard soil and obtain the load. If I say the blade has high cutting ratio, it means it can easily cut the soil and obtain the load. So, even it can handle a very hard soil conditions it can easily handle if it has high cutting ratio, so higher ratio indicates more aggressive blade.

Generally, blades which are smaller in dimension has high cutting ratio**.** Because obviously there will be more concentration of power in that the proportion of the blade, because the blade

dimension is smaller. So, those blades will be more aggressive and they will have high cutting ratio. So, the next is about the load ratio, load ratio indicates the pushing ability of the material.

So, it is nothing but the horsepower per loose meter cube of material retain in front of the blade. So, you have to clearly note here the volume of the material is indicated as loose meter cube, that means the material is in loosen state. After the material is cut, we are going to it is already in the loosened state we have excavated the material, we have cut the material, so the material is now loosen state and you are going to push the loosen material.

So, what is a pushing ability of the blade that is what is indicated by the load ratio, horsepower per loose meter cube of material retain in front of the blade is load ratio. So, it measures the blades ability to push the load once a blade is loaded. Say so, it is not referring to the blade capacity that is different. So, this refers to the pushing ability of the blade. So, generally the soil is highly dense, in that case the blade will find it difficult to push the soil.

If the soil has less density, it will be easy to push**.** So, it depends upon the type of material which we are going to push. So, generally higher load ratio means your dozer can push the load at a greater speed, it indicates the pushing ability of the material. That depends upon the type of the material which we are going to push and also depends upon the type of blade. So, as it is mentioned it is horsepower per loose meter cube of material if the blade is smaller in dimension. So, there will be more concentration of power per meter cube of material in the front of blade.

So, those blades can easily push the material. So, smaller blades will also have high load ratio. Say, it not only has high cutting ratio, it also has high load ratios, smaller the dimension more concentration of power will be there per loose meter cube of the material retain in front of the blade. So, those blades can easily push the soil to the other greater speed. So, this is how we assess the performance of the blade.

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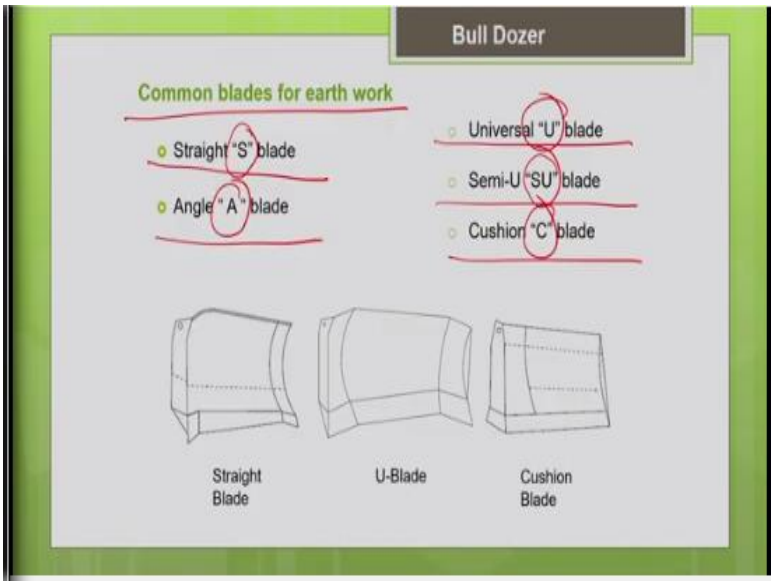

Now let us look into what are all the different types of the blade**.** These are the common blades which are used for the earthmoving operation, straight blade, angle blade, universal U blade, semi U blade and cushion blade. So, these are the standard notations used S refers to straight blade, A for angled blade, U for universal, SU for semi U and C for cushion blade. So, we are going to discuss all these blades one by one in the upcoming slides.

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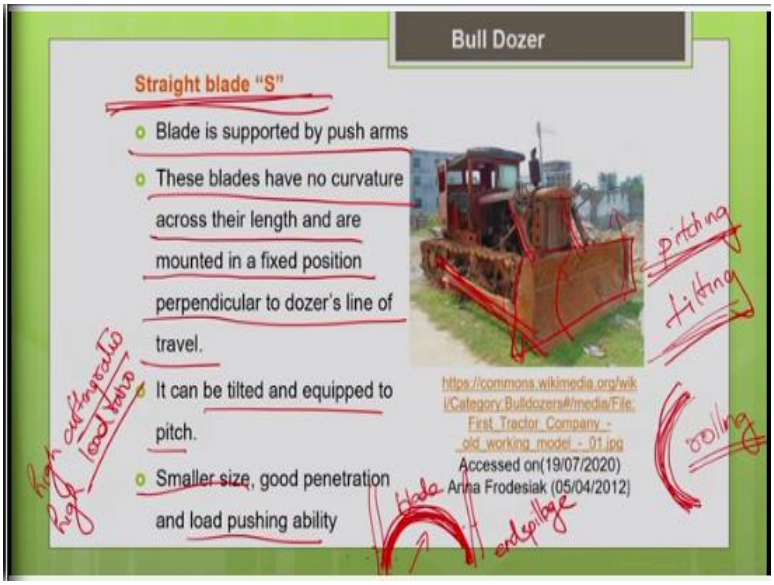

So, first we are going to discuss about this straight blade. Straight blade it is denoted as S, S blade. As the name indicates straight that means your blade is fixed straight perpendicular to the direction of the travel. So, this blade I cannot either angle it to left or right angle it to right, angling is not

possible with this blade. It is fixed perpendicular to the direction of the travel**,** so that we have to note it.

So, you can see the type of connection, these blades are commonly connected to the tractor by this kind of tilt cylinder and pusher arm arrangement. So, with this we can have the possible blade movements. So, what are all the possible blade movements with this kind of arrangement one is pitching, other one is tilting. So, only these are the 2 movements possible for this blade. As I mentioned earlier, angling is not possible with the straight blade.

So, it is fixed perpendicular to the direction of the travel, hope you remember what is pitching, pitching means you can pitch the top end of the blade forward or backward. So, tilting means I can raise one end of the blade upward and the other end of the blade I can lower it downward. So, it is a movement in the vertical plane, tilting is the movement in the vertical plane.

So, only these are the 2 movements possible with this straight blade. And another important thing to be noted is generally all the bulldozer blades most of a bulldozer blades have the curvature in the vertical plane. So, the blades will have the curvature in the vertical plane like this. So, what is the main purpose of the curvature? You can see in this picture also a curvature in the vertical plane.

So, what is the main purpose of the curvature? See you want to push the material, so the material should roll in front of the blade to facilitate a rolling effect we have this curvature. So, that the material can easily roll, for the rolling purpose to make the material easily roll in front of the blade, I have the curvature in the vertical plane. All the blades will have the curvature in the vertical plane, but there are some blades which also has a curvature in the horizontal plane.

So, some blades you can see it will have a curvature in the horizontal plane also the blade is curved like this. So, the main reason why the blade is curved like this is, so that the material will be contained inside and you can reduce the spillage of material at the ends. At the end always when the dozer, blade is pushing there will be some spillage of materials at both ends of the blade.

Say this is the blade at both the ends of the blade, there will be some end spillage. To reduce the end spillage some blades have the curvature in the horizontal plane also, that is along it is length. So, in the length also you have a curvature, so those blades are called as U blades, that we are going to discuss later. But what I am trying to say here is in the straight blade, you do not have the curvature in the horizontal plane.

So, this blade is straight, that means it has a curvature only in the vertical plane, it does not have a curvature in the horizontal plane. And this blade is fixed perpendicular to the direction of travel you cannot angle it to the left or right, this is what is to be noted. So, the blade is supported by pusher arms and tilt cylinders, the blades have no curvature across the length, and they are mounted in a fixed position perpendicular to the dozer line of, so it is fixed, you cannot angle it.

So, what are the possible moments with this blade, it can be tilted and it can be pitched. So, these plates are generally smaller in dimension straight blades are smaller in dimension. So, what are the benefits of having smaller blades? You can have high cutting ratio and high load ratio. That means these blades will have high cutting ability or penetration ability and it will also have high load pushing the ability.

So, generally when you are going to encounter hard terrain, it is preferable to go for this kind of smaller straight blades. So, it can easily handle the harder terrain.

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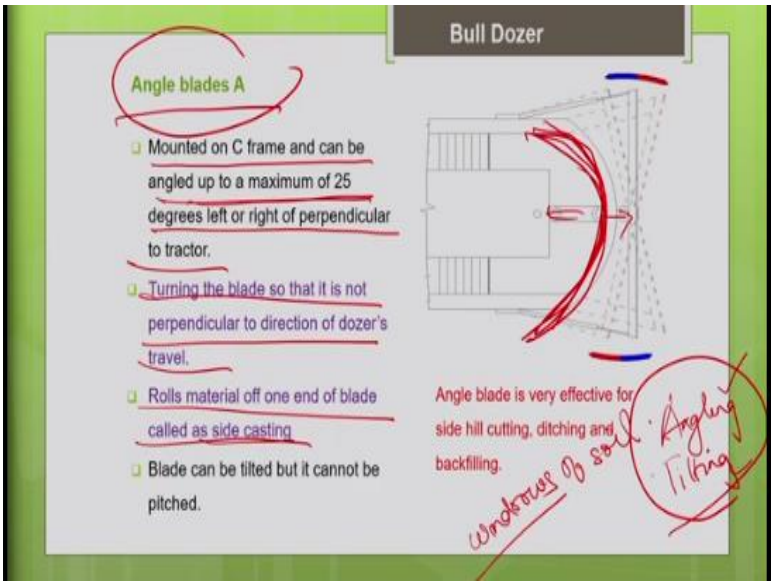

Now let us move on to the next type of blade that is the angle blade. So, these angle blades as I discussed earlier they are connected by C frame. The C frame is connecting the tractor and the blade. So, because of this C frame, it facilitates the angling moment. So, you can see the angle can be turned left or turn right to maximum of say 25 degrees. So, it is mounted on a C frame and can be angled up to a maximum of 25 degree left or right of the perpendicular of the tractor.

So, we have already discussed the main applications. So, when you are working on one side of the road or side hill cutting or if you wanted to backfill the trench, all these operations can be easily done by this angle blade. So, you can turn the blade to left or right, so that it is not just perpendicular to the direction of the dozer travel. So, this rolling the material to one end of the blade is called a side casting.

So, with this help of this blade, I can just roll the material to one end of the blade and that is called a side casting. So, this blade can easily do the stripping work and deposit the material in windrows, they call windrows of soil. So, what are the possible movements with this blade? One obviously I can do angling, I can angle it to the left or right maximum of 25 degree and I can also tilt it, tilting is also possible but pitching is not possible.

So, because of the C frame connection, I will not be able to pitch my blade. So, I cannot pitch the top end of the blade forward or backward, that is not possible with the angle blade, only possible

movements are angling and tilting. These blades are not considered as highly productive blades for earthmoving operation when compared to straight blades. So, the productivity will be only 60% of the straight blade ok. But this is for a special application as I told you.

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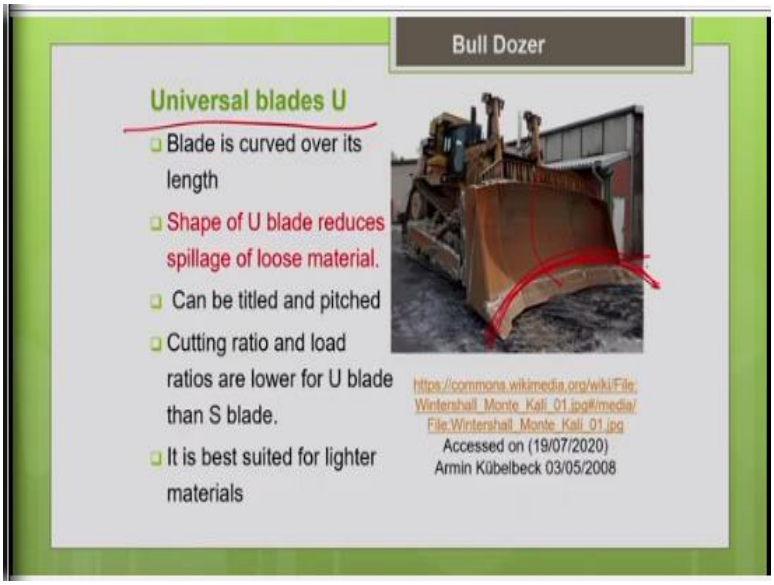

Universal blade, U blade, this is what I mentioned little bit earlier, like this blade has a curvature in the horizontal plane also. All the blades have the curvature in the vertical plane; in addition, these blades also have the curvature of the horizontal plane.

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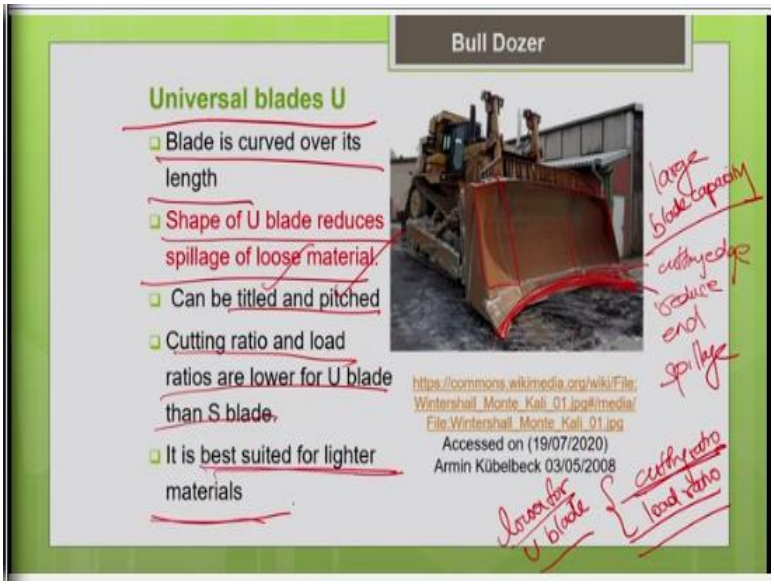

So, you can see the curvature in the horizontal plane in the form of U. So, what is the purpose of this U? So, that I can contain the material within the blade, so these are generally larger blades,

the dimension is very much bigger when compared to straight blade. You can see the kind of wings are attached on both the ends. So, they call these as wings the left wing and right wing, so it increases the dimension of the blade.

These are bigger blades you can see at the bottom cutting edge, this is the cutting edge and you can see the U curvature. So, because of this U curvature I can contain the material within the blade, I can reduce the end spillage that is a main advantage of this blade. End spillage can be reduced on both the ends. So, these plates have large blade capacity, blade capacity is high because they are bigger blades, the dimension is bigger, so that is why the blade capacity is bigger.

But one thing to be noted, the cutting ratio and load ratio these are lower for U blade when compared to straight blade. So, the cutting ratio and the load ratio are lesser for these new blades when compared to this straight blade because they are bigger in dimension. Only smaller blades can have high cutting ratio and the load ratio because of the greater concentration of the horsepower per unit meter of the cutting edge.

But here since the blade dimension is bigger, these are laser cutting ratio and load ratio. So, then why do we use this blade? See if you are going to handle some average terrain, average terrain means soil conditions are not that dense, soil conditions are not that hard to handle. So, for lighter materials, it is the right choice it can easily push the lighter material which are the less dense and you can use it for a relatively longer distance less end spillage. Because of the U curvature the end spillage is less.

For those applications you have to choose this new blade. So, you can see the blade is curved over it is length, the shape of U blade reduces the spillage of the loose material. So, the possible movements of tilting and pitching, for this blade only tilting and pitching possible, only for the angle blade you can do angling. For all the other blades you can see that most of the other blades you can see the common movements possible are only tilting and pitching. Cutting ratio and load ratio are lower for U blade than the S blade. It is it is best suited for the lighter materials.

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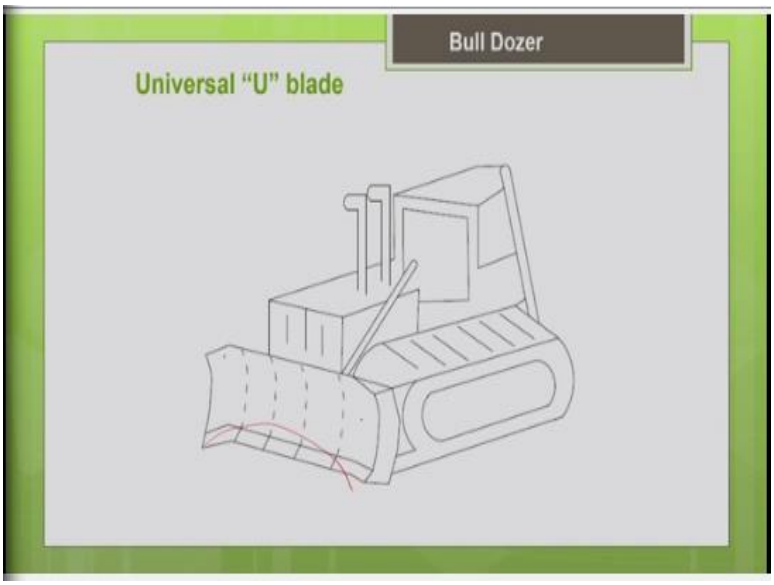

So, this is again a schematic sketch showing the U blade connected to the bulldozer, you can see they are larger in dimension and they have a U curvature. And you can see the wings attached on both the ends.

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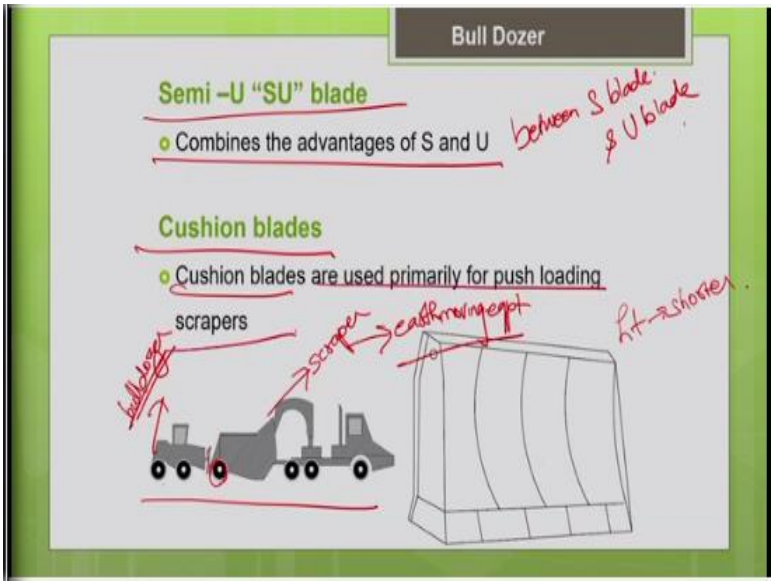

Now let us see what is this SU, semi U blade. It is something between straight blade and U blade, it is between S blade and U blade. That means it is dimensions bigger than the S blade but smaller than the U blade. Similarly cutting ratio is the lesser than the S blade but better than the U blade. So, it is something between the S and U blade. So, accordingly you have to make the choice according to your requirement.

Then let us see what is this cushion blade, I have shown this picture earlier. So, when we discussed about the application of bulldozers, I told you that the bulldozers are also used for supporting the other machines, so it helps in assisting the other machines in it is job. Say this is the schematic sketch showing a scraper. So, this is the bulldozer, so your bulldozer is helping to push the scraper.

So, this scraper is also when earthmoving equipment, we are going to discuss about this equipment in detail in the next lecture. This scraper has a bowl and a cutting edge. So, the scraper will cut the earth and fill the bowl that is called as a loading operation. So, during the loading operation, I have to supplement the power of the scraper with the help of a pusher, this pusher is nothing but your bulldozer.

So, this bulldozer will supplement the loading power of the scraper thereby you can enhance the productivity of your scraper. So, only during the loading operation I need the help of the bulldozer. So, for those bulldozers, so I am not going to use the blade for earthmoving operation. So, I need a blade for just pushing the machines that blade is called as cushion blade, C blade.

These blades are generally the height will be shorter. So, that the height of the blade, the blade will not disturb the rear wheel of the machine which it is pushing. So, the blade height is shorter and this blade no movement is possible, I cannot tilt or pitch or angle nothing is possible with this cushion blade it is just fixed. So, these cushion blades it is productivities also less**.**

With respect to earthmoving operation it is not commonly used for earthmoving operation, it is used primarily only for pushing the other machines. So, we have discussed about different types of blades so far. So, straight blade, U blade, angle blade and cushion blade and SU blade. Straight blade as I told you for harder terrain, you have to go for straight blade, because their cutting ratio and load ratio is high.

But the problem with a straight blade is you will have end spillage, when you push the earth, there will be spillage of material at both ends of the blade that will reduce the productivity of the bulldozer. So, in that case I have to go for the U blade, if you wanted to reduce the end spillage, you are going to push the material for a longer distance and if the material is easier to handle it is

preferable to go for U blade. Because U blade has a greater blade capacity also, bigger in dimension. So, similarly the cushion blade it is used only for pushing the other machines, when the bulldozer is used for assisting the other machines then it you can go for the cushion blade.

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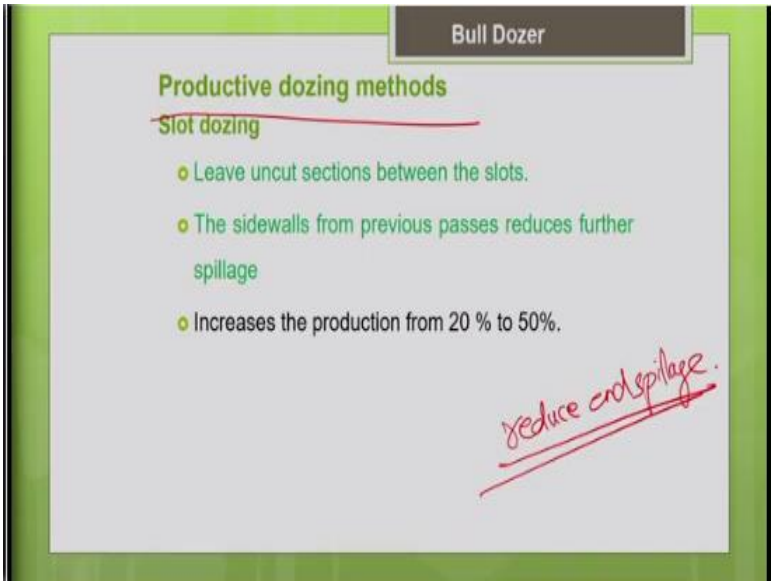

Now let us see what are all the different the dozing methods which are commonly adapted to enhance the productivity of the bulldozer. To enhance the productivity of the bulldozer, I need to reduce the end spillage of the material which is happening at both ends of the blades. How to reducing the end spillage? What are all the dozing methods which can help me to reduce the end spillage?

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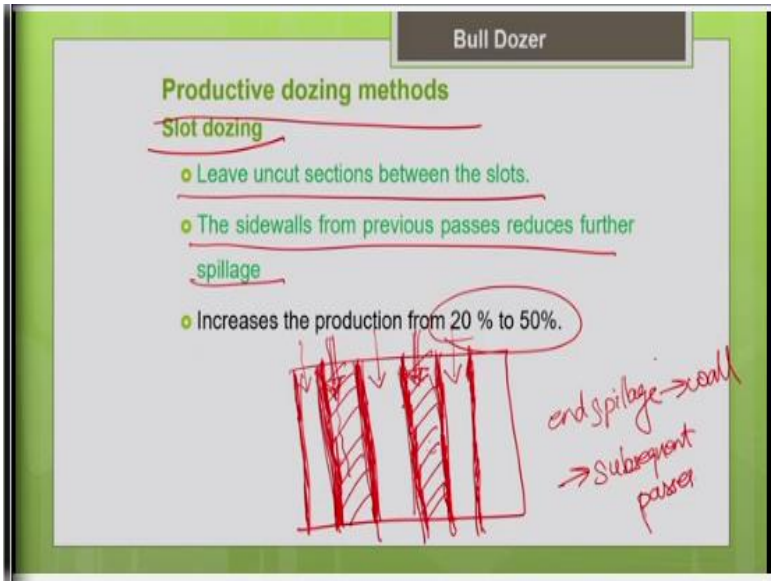

So, one such method is your slot dozing method, slot dozing. So, basically how to carry out this slot dozing? You have to divide your land, your area where you are going to do the dozing operation into many parallel cuts divided into parallel cuts. So, if you have a larger area, it is easy to implement this method. Divide your area into parallel cuts and allow the bulldozer to move through alternative cuts first, let it move through alternative cuts first.

So, when the bulldozer is moving through these cuts obviously at the both the ends you can see the end spillage will be there. As the bulldozer is pushing the earth there will be end spillage of material at both ends of the path, so here also the end spillage is there. So, now this end spillage will act like a wall, for the subsequent passes.

So, now after this, now you allow the bulldozer to go through the gap between the 2 cuts. So, now we are going to allow the bulldozer to go through the gap between the 2 cuts. So, when this is now going to this gap already the end spillage which is formed back by through the earlier passes, this is acting like a wall. Since this act like a wall the spillage, further spillage is reduced when the bulldozer is passing through this path.

Similarly, when it is passing through this path already you have end spillage formed here, that will act like a wall. So, this wall will prevent the further spillage during this pass. By this method, I can reduce the spillage and I can increase the productivity from 20% to 50%. So, basically you are going to leave some uncut section between the slots. So, these are the uncut sections, so you have left the gap between the slots.

So, first you finish these slots, then come back to this uncut section, when you do this section, the earlier passes spillage will act like a wall for this the passage, so this will further prevent the spillage. So, the sidewalls from the previous passes reduces the further spillage. So, this will increase the production as I told you from 20 to 50%. This is one method which is commonly followed to reduce the end spillage and to increase the productivity of the bulldozer.

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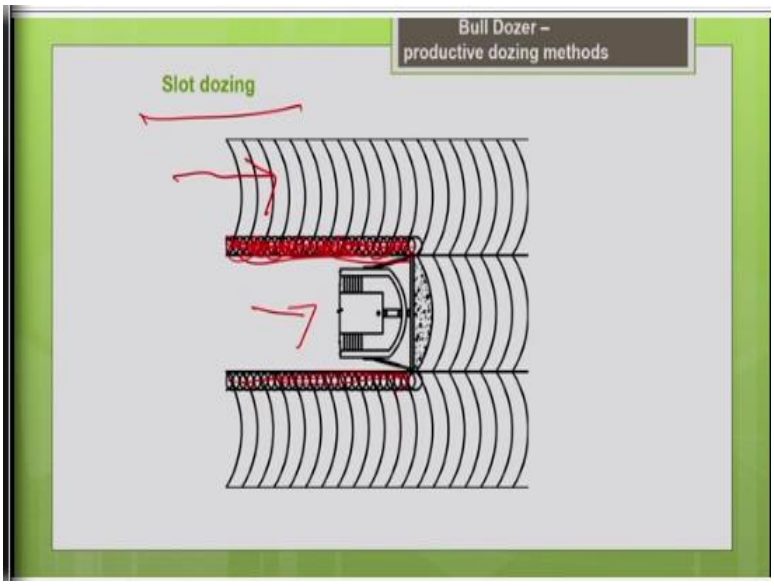

So, this picture also indicates the slot dozing. So, you can see when the bulldozer is moving through this particular cut, you can see the end spillage being formed at both the ends of the blade, this is the end spillage. So, after this, so when you go through the other paths. So, this end spillage will act like a wall for the subsequent passes, the end spillage formed during this particular pass will act like a side wall for the subsequent passes when the bulldozer is passing through this path, this will act like a wall and prevent the further spillage.

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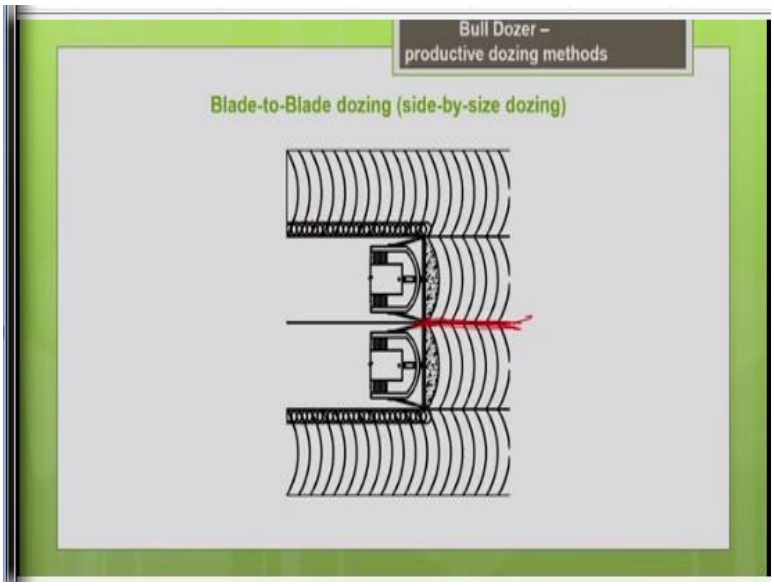

Now let us see another method of productive dozing method to reduce the in spillage. So, here what we are doing is we have to employ 2 bulldozers together and maneuver it in such a way that the blades are coming closer to each other almost touching the blades are brought closer to each

other. So, when the blades are closer to each other, obviously you can reduce the end spillage between these blades.

The spillage of material between the blades can be reduced. So, but the thing is there will be some additional time taken for maneuvering. The driver or the operator should be skilled enough to maneuver both bulldozers in such a way that the blades are closer. So, by this I can reduce the end spillage at the end of the blade. Obviously, the spillage is here but the spillage can be reduced here.

So, but this cannot be adopted for a very short distance for a very, very shorter haul distances because you need some sufficient time for maneuvering. So, there should be some sufficient distance, so that you can maneuver.

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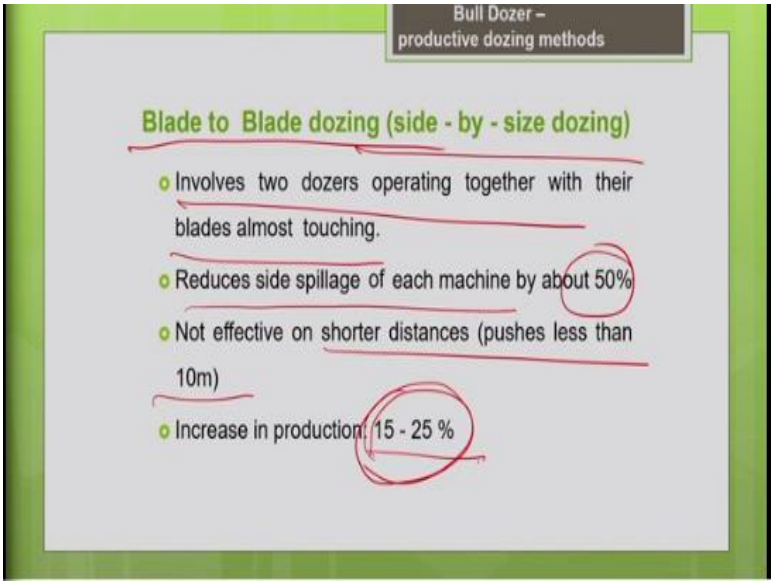

So, this blade to blade dozing it is also called as side by side dozing. Involves 2 dozers operating together with their blades almost touching, it reduces the side spillage between each machine by about 50%. But as I told you like some amount of time is needed for maneuvering, that is why I cannot use it for a very short distance say less than 10 meters, I cannot adopt this method.

So, because of the increase in the maneuvering time the effective increase in production you can see it will be about 15 to 25%. So, though it reduces the end spillage to certain extent, but it increases the maneuvering time, so the effective increase in production will be from 15 to 25%.

So, we have discussed about different types of blade movements and we discussed about the types of blades, how to assess the performance of the blade**.**

And also, we discussed what are the productive dozing methods to reduce the end spillage and to increase the productivity of the bulldozer. Now let us see what are all the factors which affect the productivity of the bulldozer?

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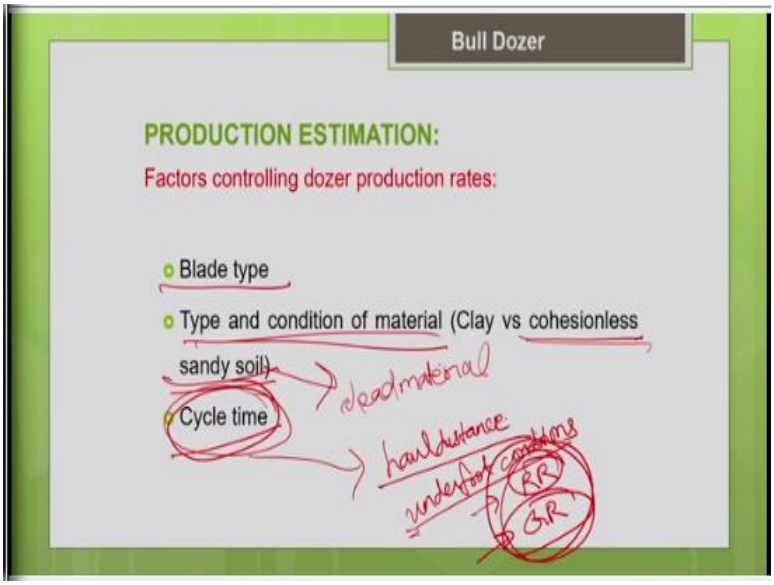

So, obviously your blade type will affect the productivity and the material with the blade is going to push the type of the material, the density of the material all these things will affect the productivity of the bulldozer. How the blade type will affect, we know it already, we have different types of blades straight blade, U blade, angle blade. So, as I told you for hard terrain straight blade will give you high productivity.

So, if it is just an average terrain, loose soil I can use U blade, there U blade will be it will be more productive. So, then angle blade, it is for a special application, angle blade is not that highly productive in earthmoving operations when compared to straight and U blade. So, depending upon the blade type, your productivity will vary. And as I mentioned earlier the material type, if the material is going to be cohesive, it is easy for the material to roll in front of the blade.

But if it is going to be cohesion less sand, the sand will act like a dead material**,** it will not roll in front of the blade. For this sandy soil, it is very difficult for the blade to push the soil, so the productivity gets affected. So, the type, the density of the soil, everything affects. If it is going to be denser material, it is difficult for the blades to push, if it is going to be less dense, it is easier for the blade to push, so accordingly the productivity will vary.

Then the cycle time, the cycle time it depends upon how much distance you are going to travel, say the haul distance, your path, so the which route you are adopting. So, what is the condition of that haul route? The project conditions, the underfoot conditions, the underfoot conditions are going to affect your cycle time. Say what is the rolling resistance, what is the grade resistance which are prevailing there**.**

Whether you are going to move up the slope or down the slope, all these things will affect the cycle time. So, your haul distance and the project underfoot conditions, the site underfoot conditions, the resistance is which the vehicle is going to encounter, all these things will affect the speed of the machine. And that is going to affect your cycle time.

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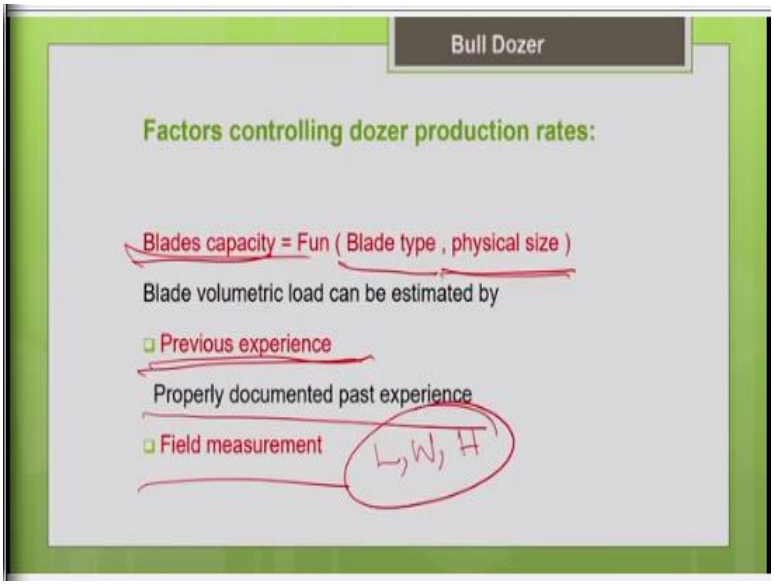

Now let us see how to estimate the blade capacity. The blade, so it is not like a bucket or bowl. So, how much material lies in front of a blade that defines the capacity of the blade. It depends upon your blade type and the dimension of the blade. Obviously as I told you straight blade are smaller

in dimension when compared to U blade. So, the greater the dimension, bigger the blade, your blade capacity will be more.

So, how to get the information on the blade capacity? I can get it from the manufacturer**.** So, the manufacturer will provide you the specifications like what is the capacity of the blade; I can get it from the manufacturer or from your own previous experience. So, for a similar type of blade and for a similar type of a dozer and for the similar type of terrain the material, soil. So, from your properly documented past experience, you can get the blade capacity, that is also possible.

Or you, yourself can do the field measurement at your project site. So, do the dozing operation, obtain a heap of earth in front of the blade. So, now you find what is the length of the pile along the length of the blade? Then perpendicular to the blade, what is the width? And what is the height of the pile? So, based upon the dimensions of the pile of material you can find the blade capacity.

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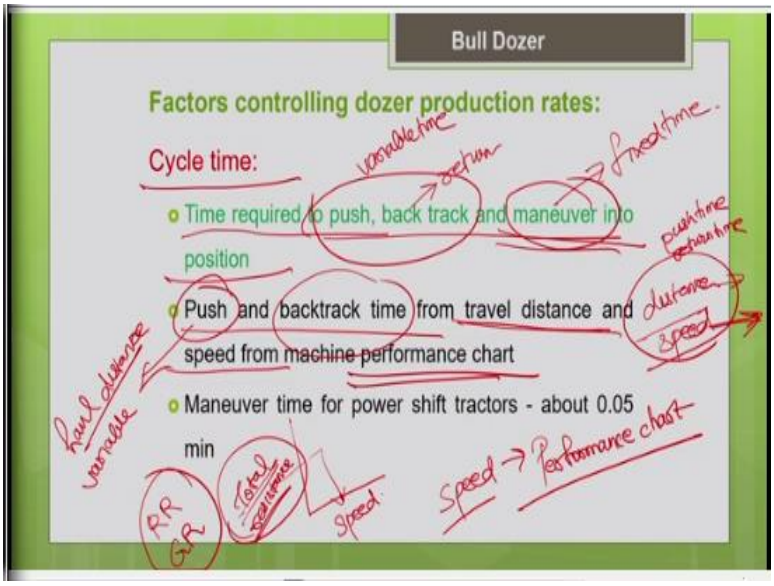

So, now let us see how to define the cycle and estimate the cycle time of the bulldozer. Say the bulldozer is used for earthmoving operation, how to define one production cycle of bulldozer? So, basically the bulldozer will cut the earth, once the blade is full, completely loaded, it will just push the earth till the dumping place, then it will return back to it is original position where you wanted to do the dozing operation again.

So, this cutting and pushing will go together. So, the time required to push, backtrack and maneuver into position, so that is called as a cycle time of the bulldozer. So, you are going to cut the earth, push the earth, dump it at the required place, then backtrack, backtrack in the sense you are going to return, return back to the original position where you want to do the dosing operation again.

So, other things are maneuvering, maneuvering in the sense whatever adjustments you do, like for increasing the speed, accelerating or decreasing the speed, changing the gear, so the time needed for changing the gear, all those things comes under the maneuvering. So, we call this as fixed time, this is fixed time and this one is variable time, your push and backtrack it is called this variable time, why do we call this push time and backtrack time as variable time?

Because it is variable depending upon your haul distance. So, greater your haul distance greater will be a push time and return time or backtrack time. So, this is solely dependent upon your haul distance, so this is dependent upon your haul distance, so that is why we call it as variable obviously it depends upon the speed also. So, to know the push time and the backtrack time, I need to know the travel distance or the dozing distance or the haul distance**.**

I need to know the travel distance and I also need to know the speed. So, you very well know how to determine the speed. So, in the earlier lecture, I discussed about how to determine the speed from the performance chart. So, with the help of the performance chart, you can determine the speed. So, in the performance chart, you will be having the speed in the x axis and you have the say total resistance either in percentage or in rimpull in kg it is given.

So, based upon the total resistance you can find what is the speed possible for that particular project condition, you can find from the performance chart, you can refer to the previous lecture to collect the information regarding this. So, basically if you know your project conditions that means what is the total rolling resistance in your site. So, that depends upon your terrain condition.

And also, if you know what is the grade resistance whether you are going up the slope or down the slope**.** If you know that you can find the total resistance and accordingly what is the speed possible,

I can determine from the performance chart. So, once you know the speed and once you know the distance, I can calculate the push time and the return or the backtrack time.

So, for that I need to know the distance, dozing distance and I need to know the speed, speed I can determine from the performance chart. So, now let us see what is this maneuver time? So, already I told you maneuver time is nothing, but the time needed for changing your speed accelerating, changing the gears, or reducing the speed, so that is what is called as a maneuver time. So, this maneuver time will depend upon the type of transmission. So, in the all the machines, there are 2 types of transmission possible.

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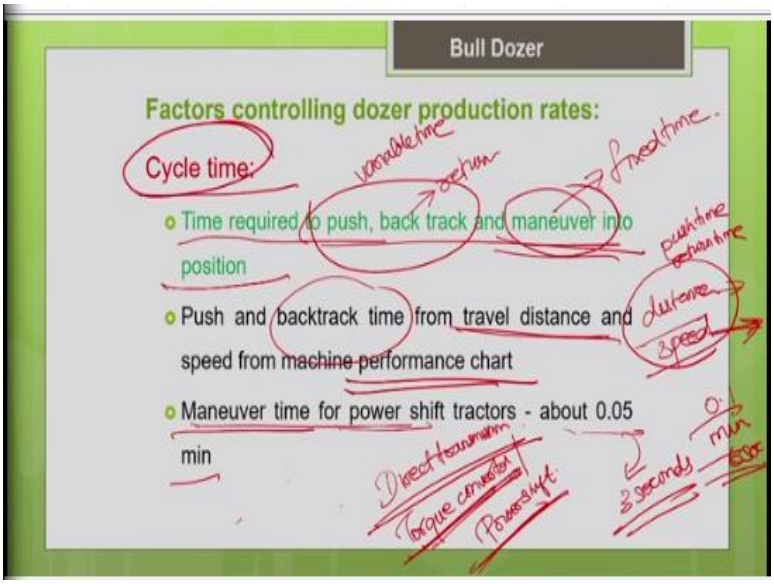

One is either you can have direct transmission or you can have this torque converter mode or power shift. Direct transmission is nothing but manual gear change. So, the operator has to manually change the gear depending upon the load conditions. Here the torque converter it will automatically match the engine output according to the load condition, you need not change the gear manually in the torque converter, it is automatic gear change.

So, depending upon this transmission mode, your maneuver time will change. Say if you are going to go for power shift that is automatic gear change, the maneuver time is 0.05-minute, 0.05 minute in the sense 3 seconds. But your manual gear change that is direct transmission if you go for it will be 0.1 minute, say 6 seconds. So, you need to know that based upon the mode of transmission

whether manual gear change vehicles or automatic gear change vehicles depending upon the time taken for the maneuvering also will vary.

So, that will also affect the total cycle time of the machine. So, if we want to make an accurate estimate, you have to consider all these things.

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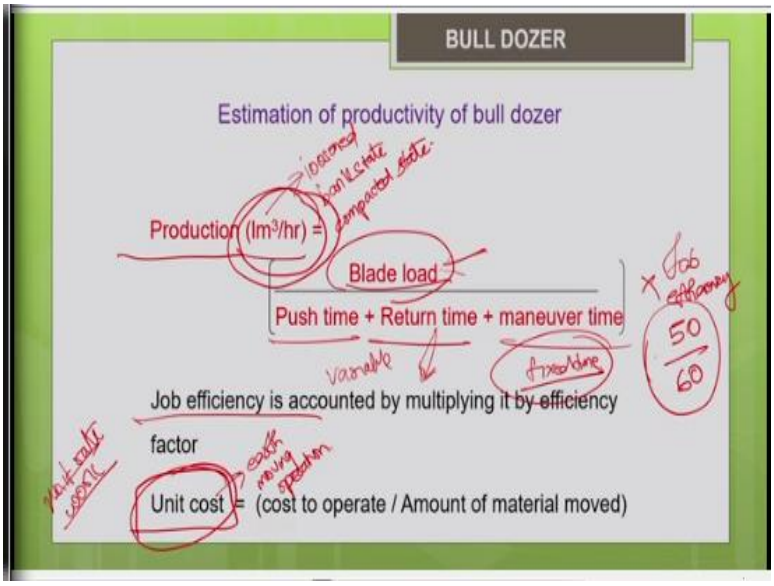

Now let us see how to estimate the productivity of the bulldozer. So, we are going to estimate the productivity a lose meter cube per hour. As I told you whenever you express the volume, you should be very specific that whether you are expressing the volume in the loosen state or bank state, that is natural state or in the compacted state. So, in which state you are referring to the material that you have to clearly specify, so then only it has a real meaning.

So, the production here is expressed in loose meter cube per hour, that means you have cut the earth and loosen the material after loosening in it, what is the productivity, that is what the loosen state we are measuring it. So, it is nothing but your blade load divided by the cycle time. So, how to determine the blade load just now we discussed. So, you can get it from the manufacturer, what is the blade capacity or from your own past experience you can get it.

Or you can do the field measurement yourself and find the dimension of the pile of material lying in front of the blade and determine the blade capacity. So, this is how you determine the blade

load. And cycle time, so the cycle time is made up of push time, return time and the maneuver. So, these 2 are variable and this one is fixed time. So, just now I explained how to calculate push time, it depends upon the haul distance and the speed of the machine.

That speed depends upon the actual project condition, underfoot conditions in your project site. Obviously, the return time will be less when compared to push time, because in the return time your blade will be empty, it is an unloaded condition. So, the machine can travel faster when compared to the onward journey. So, maneuver time, you know depending upon whether manual gear change or an automatic gear change, the time will vary.

So, after estimating this, you have to take into account the job efficiency. So, one thing you should know that your machine is not going to be operated for the entire 60 minutes in an hour. So, depending upon your project condition, it may operate for 45 minutes or 50 minutes. So, it may even operate only for 30 minutes, it depends upon your project condition. So, how much time the machine is operated in an hour?

So, that is what is a working efficiency or job efficiency, that you have to take into account and multiply this by the job efficiency. So, how do you multiply? Say my machine is working for 50 minutes an hour then 50 divided by 60, this is my efficiency factor, you have to multiply the productivity obtain with this efficiency factor. So, after this you have to calculate the unit cost of production.

This is a very important because as I told you, when you prepare for bidding when you plan for bidding in unit rate work, in unit rate contract unit rate work. We are very much interested in this data, what is the unit cost associated with every activity, unit cost of earthmoving operation. So, what is the unit cost of earthmoving operation?

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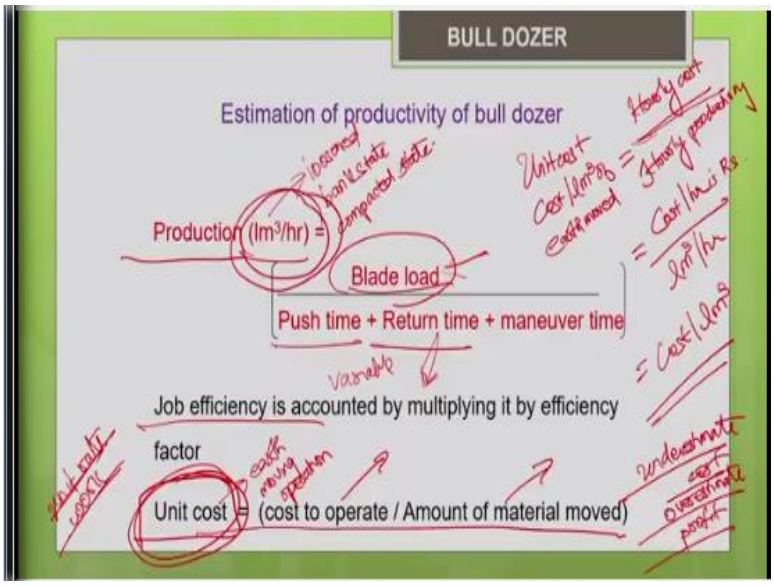

So, for that you need to know unit cost is nothing but cost per loose meter cube. Say I am going to find it in the loosen state cost per meter cube of earth moved, I need to calculate. It is nothing but your hourly cost associated with the machine divided by the hourly productivity. If we know these 2 data I can calculate. So, by now you should be knowing how to estimate the cost associated with the machine.

I have dedicated so many lectures on how to estimate the ownership cost and operating cost associated with the machine. So, you can refer to those lectures again and find out how to estimate the hourly cost associated with the machine. You have to add all the components the ownership, operator cost all those should be added here to get the cost per hour.

So, you know the cost per say in rupees divided by the productivity of the machine in loose meter cube per hour, what is a productivity? So, if you know all these data, you can find what is the cost per loose meter cube of the earth, so this is the unit cost of production. So, this is the data which we will be commonly using this will be a part of what you quote in your bid, unit cost of production of this activity forms a part of a unit cost what you generally quote in your unit rate contract bidding.

So, that is why the estimation of this is very important, and you should accurately estimate it to the best possible, so that you can properly plan for a bidding. Otherwise, as I told you earlier, many

times if you do not have a thorough knowledge on how to estimate the cost and how to estimate the productivity associated with the machine, you may underestimate the cost. So, if you underestimate the cost what happens?

So, you may overestimate your profit, because this is what happens in many cases. Because if you do not have thorough knowledge on how to estimate the cost and how to estimate the productivity, so this will finally you will end up in problem, you may not be able to realize the real profit which you have estimated in the paper. In real scenario, you will not be able to realize those profits and you will end up in problem.

So, what we discussed is one way of estimating the productivity. So, for that you need the information on the blade capacity and you need the information of the haul distance and you need the information on the rolling resistance and grade resistance, so that I can find the speed of the machine with that I can calculate the productivity. So, another shortcut method.

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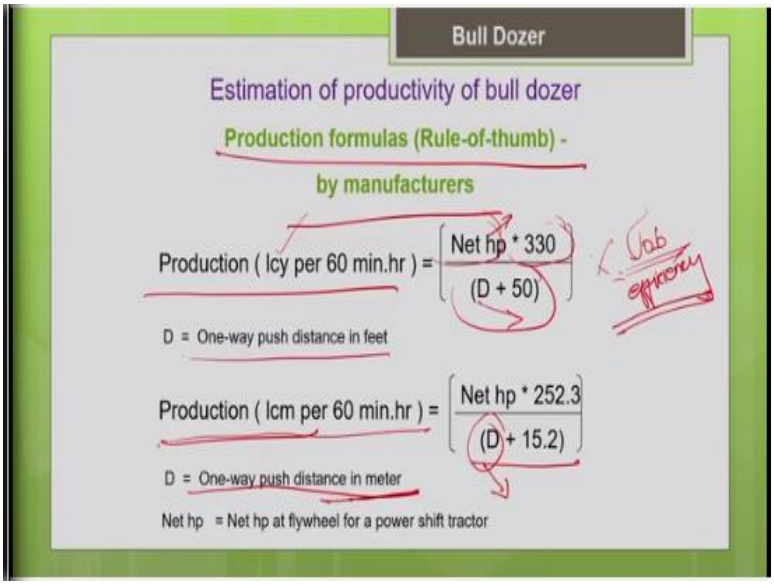

So, there are some thumb rules available provided with a equipment manufacturers. So, if you know the horsepower of the tractor and if you know the dozing distance, one-way push distance you can directly estimate the productivity of the bulldozer, these are thumb rules. It is nothing but your say net horsepower multiplied by 330 divided by D + 50**,** D is your one-way push distance or dozing distance in feet.

So, the final resulting value of production will be in loose cubic yard per 60-minute hour. So, that means, it is considered that the machine is operating for 60 minutes in an hour. So, when you use this thumb rule, according to your working efficiency or the job efficiency in your project site, you have to multiply this value with the job efficiency for your project site condition. Whether you are going to work for 45 minutes in an hour or 50 minutes in an hour, you have to apply that to this value.

So, in loose cubic meter per 60 minutes hour if you want to estimate the production you can follow this formula net horsepower multiplied by 252.3 divided by the D + 15.2. Here the dozing distance is given in meters. Here one-way push distance in meter, it is given in meter, final production value is loose cubic meter. So, these are just approximate thumb rules to approximately estimate the productivity.

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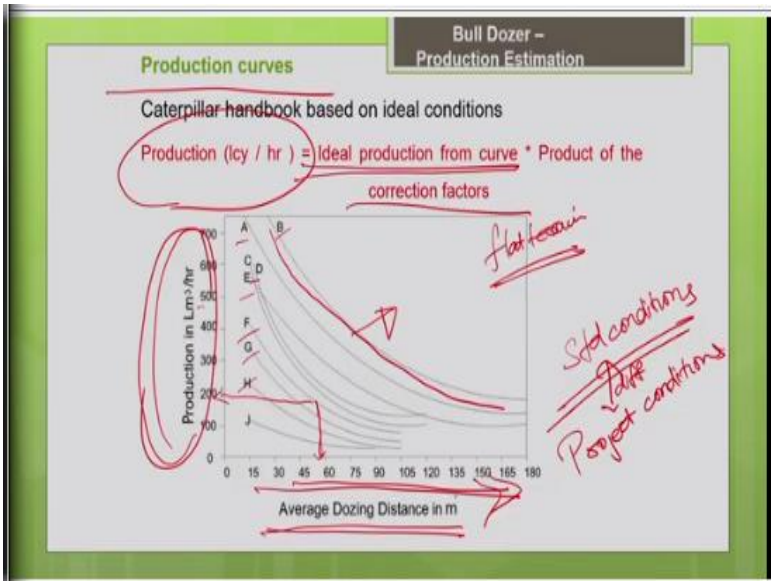

So, there is also another approach to determine the productivity. So, with the help of production curves, say some of the equipment manufacturers they do supply these production curves for the different models which they have manufactured. So, from this production curves, this just show some sample curves and schematic diagram, these are not very accurate, I am just trying to show the trend of the production curves and the application the production curves.

So, the real production curves information, you can get it from the equipment handbook. So, say for example caterpillar handbook. If you look at the caterpillar handbook, you can see these production curves are supplied by the manufacturer for different models, you can go through the handbook. And also, in some literatures like the textbook by peurifoy it you can find that these production curves are available, you can go through that.

These are just some schematic lines to show the trend. So, you can see these production curves will have a relationship between the dozing distance and the production. So, you have the average dozing distance in meter in the x axis and you have the production in loose meter cube per hour in the y axis. And all these refers to different models of machine produced by the manufacturer. So, A, B, C, D you can correspondingly look into the model.

So, you can see that as the dozing distance increases your productivity is getting reduced. So, if you know your equipment model number, so refer to the appropriate equipment handbook look for the appropriate model number and choose a production value directly. So, if you know the dozing distance, say the dozing distance is 60 meter and the model number is say F.

So, you can directly calculate the production value. So, if you know the dozing distance, if you know the model number say the model number is say F, you can calculate what is the productivity, you can choose the value from these curves directly. But one thing you should know that these productivities, the production curves are drawn assuming some standard conditions**.**

They are applicable only for standard conditions, which they have assumed for drawing these curves, but your project conditions your project site conditions will may differ from the standard conditions. So, will be differing mostly it will be differing. So, your project the conditions if it differs from the standard conditions, then accordingly you have to apply some correction factors.

So, how are we going to estimate the productivity? Choose the ideal production from the curve, as I told you if you know the dozing distance, if you know the model number directly you can choose the ideal production value from the curve. Then according to your project site conditions, apply the correction factors what are all the correction factors we are going to discuss next**.** Then multiply

both you will get the actual production for your actual site condition. So, we are going to discuss how to estimate that.

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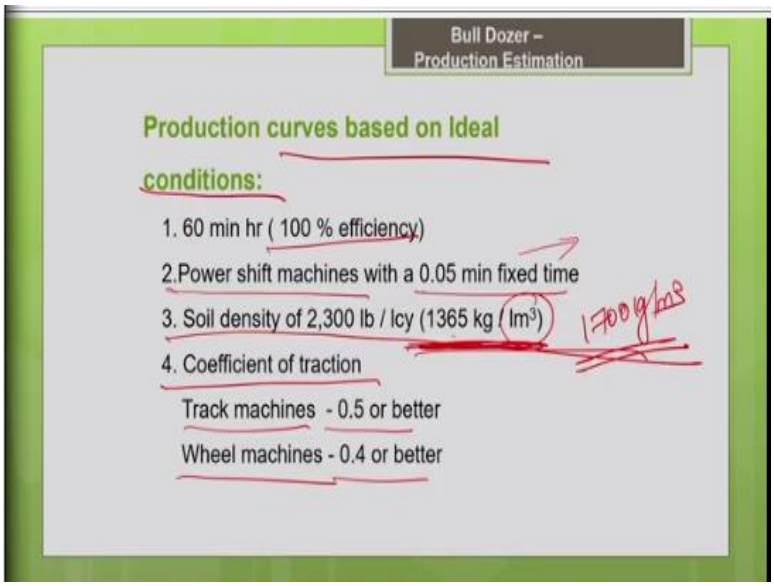

So, as I told you these production curves are drawn based upon ideal conditions. What are all ideal conditions? It is drawn assuming 100% job efficiency, that means your machine is going to work for 60 minutes in a hour, so that is what is the assumption. But in your real project site, your machine will be working just for 30 minutes or 45 minutes or 50 minutes. So, you have to apply the correction factor accordingly.

Then it is based on the assumption that the machines are power shift machines, that means they are based on torque converter, automatic gear change. So, they are maneuver time is only 0.05 minute but if your machine which you are going to use in your site is based on direct transmission, manual gear change, then accordingly this extra time will vary. It may be 0.1 minute, so you have to apply correction factor accordingly.

And the curve is valid only for this soil density of say 1365 kg per meter cube**,** it is given in loosen state. But the soil which you are going to handle in the project site, say if it is denser than this, say if it is 1700 kg per meter cube**.** Obviously, your productivity will get reduced; if it is going to be denser than this obviously which you are going to realize will be lesser. So, in that case you have to apply the correction factor accordingly.

Then the coefficient of traction assumed for the track machines is 0.5 or better than that or wheel machines it is 0.4. So, in a project site, if the coefficient of traction is going to be lesser, so then accordingly, you have to adjust the productivity which are chosen from the curves, you have to apply the correction factor. If the traction is going to be lesser your productivity will also be reduced, how much percentage is going to reduce? It depends upon the correction factor that you can refer the literature for the correction factors.

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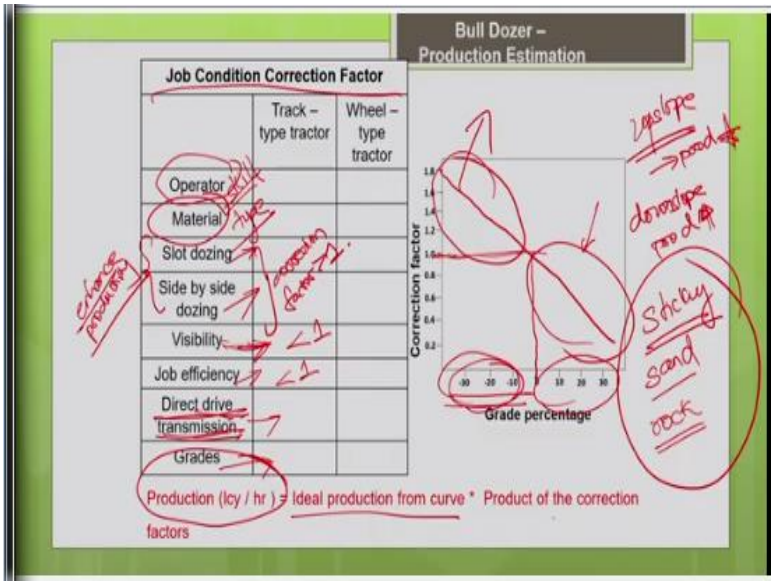

I am just giving you a broad guideline, you have to refer to the either the equipment handbook or the appropriate textbook as I mentioned by Peurifoy et al. So, that you can get these values you can come to know about these values. So, this table shows you what are all the correction factors which are to be applied for that particular curve. So, as I told you, you are going to use this curve, you are going to use a value from this curve which are valid for a standard condition.

So, according to your project condition, you have to apply the correction factor and adjust this value, that is what we are going to do. So, what are all the correction factors say depends upon the operator skill. Say that curve, the ideal curve was based on the assumption that the operator skill is excellent. But if your operator skill is poor, then accordingly you apply the correction factor, what is the correction factor? You refer the literature and pick up the value.

Similarly, the material type, your material is a very tough material, say as it will it is very sticky to handle, then in the case of productivity will be less. In the same sense if the material is going to be totally non-cohesive sand, in that case also it will not easily roll in front of the blade. So, that case also productivity is going to be less, if it is going to be rock pieces, short rock, it is going to be difficult for the blade to push.

See, in all these cases, you have to apply the correction factor according to the type of material, so those factors are available in the literature. Then if you are going to adopt some productive dozing methods, like slot dozing, side by side dozing, that is what we discussed earlier. So, these protective methods will enhance the productivity by reducing the end spillage. So, in this case it is going to be better than your ideal condition.

So, whatever you have chosen from this curve, we have chosen values from this curve. So, your value should be better than this curve, because you are adopted slot dozing method or side by side dozing method. So, in this case your correction factors will be greater than 1 because your productivity will be increasing. Similarly, visibility, if you are working in a place in a foggy area, dusty area, visibility is very poor.

In that case, you have to reduce the productivity taken from the ideal curve. So, that means a correction factor will be lesser than 1. Obviously in most of the cases, your machine will be working for 45 minutes or 50 minutes in a hour. So, in that case we have to apply the job efficiency, so accordingly the correction factor will be lesser than 1. So, the curves valid for power shift mode, that means torque converter mode, automatic gear change.

If you are going for direct drive, the maneuver time will increase, so your productivity will be reducing, accordingly you have to apply the correction factor. And depending upon the grade percentage, that means slope. So, this curve value is based on the assumption that you are operating the machine on a flat terrain. But in your real project site, if you are going to move up the slope or down the slope, then accordingly a productivity will vary.

if you move up the slope your productivity will decrease obviously, your grade resistance will increase, your speed will reduce, your cycle time will increase, your productivity will reduce. If you move down the slope your productivity will increase, why the productivity increases? your machine speed will be more when you move down the slope. As the machine speed is more the cycle time is reduced, so the productivity will be increased.

So, according to the percentage of slope in your haul route, you have to calculate the correction factor. Say your ideal curve is based on 0 that means it is for a flat terrain, the correction factor is 1. If you are also going to work on a flat terrain, you need not to apply any correction factor, correction factor is just 1. But if your terrain is going to be down the slope, say the slope percentage is 10% or -10%, -20% or -30%.

In that case, your productivity will be increasing. So, that means your correction factor will be greater than 1, so it will go like this. So, this curve you can get it from the equipment handbook or the literature, I have just drawn it approximately to show you. So, if you are working in down the slope, my correction factor is greater than 1. If I am working up the slope, my correction factor is less than 1.

It is because down the slope my productivity is going to be high, up the slope my productivity is going to be lesser, that is why my correction factor is less than 1. Once you take up the correction factors from the literature or the company handbook and you have chosen the productivity value from the ideal curve you multiply both, you will get the real production value for the actual project condition, so this is how you have to estimate.

So, we will work out a problem using this methodology, so that you will understand better. So far we have discussed about 3 different approaches to estimate the productivity of the bulldozer one is using the production curves.

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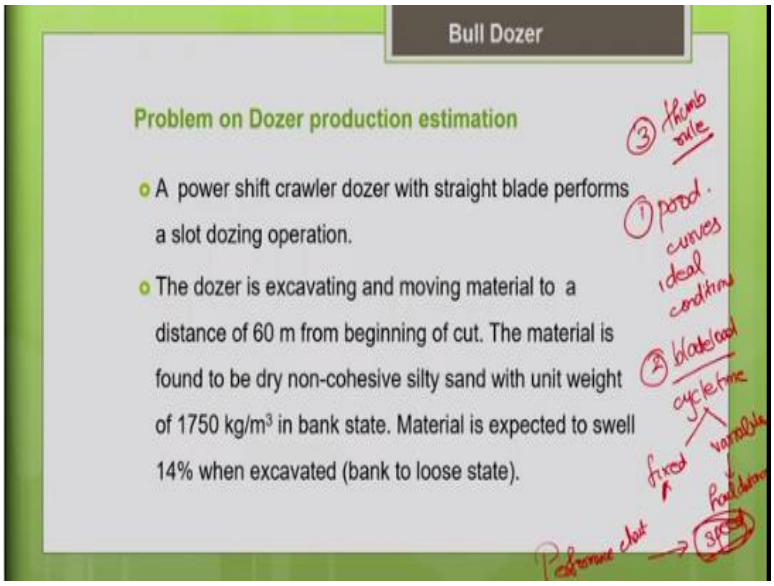

So, using production curves, which are drawn for the ideal conditions? So, we choose the value from the corresponding production curve which is supplied by the manufacturer. And apply the correction factors according to the project conditions and find the actual productivity for the project conditions, that is one way. The other method we learnt is, so we need to estimate the blade load**,** we need to know the blade capacity and then we need to determine the cycle time.

So, like how to determine the cycle time? To determine the cycle time, you need to know the distance. So, all the parts of the cycle time say your fixed cycle time and the variable cycle time. So, fixed is nothing but your maneuver time like depending upon weather the mode of transmission is direct or manual gear change or it is power shift mode or torque converter automatic gear change, accordingly your maneuver time will vary.

Then the variable time, so if you know the haul distance, if you know the dozing distance and if you know the speed of the machine, you can calculate the variable time. So, to know the speed of the machine, you can take the help of the performance chart. So, you know already how to use the performance chart. Say for example if you know the actual project conditions like what is the rolling resistance, what is the great resistance.

Then using the performance chart, you can find the corresponding speed corresponding to the total resistance. So, from that you can find the speed, so that will help you to find the cycle time, so this

is one approach. The other approach is a thumb rule formula. Your thumb rule formula, as a function like your productivity as a function of the horsepower of the machine and the dozing distance.

So, this formula available in the equipment handbook supplied by the manufacturer. So, there are different approaches to estimate the productivity of the machine. So, let us work out some problems, so that we will understand better how to estimate the productivity of the bulldozer.

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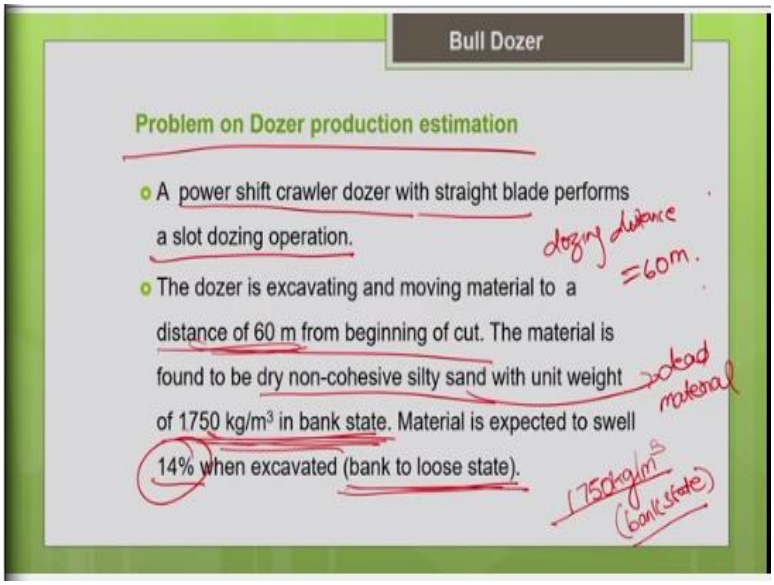

In this problem we are going to estimate the productivity of this power shift crawler dozer. So, power shift, so it is automatic gear change, so you can assume the maneuver time. The dozer is with a straight blade, it performs a slot dozing operation. The slot dozing operation you know that we adopt it, so that we can reduce the end spillage and you can increase the productivity of the bulldozer.

In this method for this particular project, we have adopted slot dozing operation. And the dozer is excavating and moving material to a distance of 60 meter from the beginning of cut. So, the dozing distance is given, your dozing distances 60 meter. The material is found to be dry non-cohesive silty sand, so I hope you remember. So, the productivity of the bulldozer depends upon the type of the material.

If it is going to be cohesive material, it will be easy for the material to roll in front of the blade. So, in that case pushing will be easier and the blade will have a higher productivity, but in this case in your problem it is given that it is dry non-cohesive silty sand. So, this kind of material will behave like a dead material, it will not roll properly in front of the blade. So, it is productivity is likely to be low, that we have to note it. And the unit weight of the material is given 1750 kg per meter cube in bank state.

So, you have to clearly know that the volumetric measure is clearly specifically expressed in bank state. I hope you remember what is bank state, bank state is nothing but the natural state before you disturb the earth or before you excavate the earth, that natural state is called as the bank state. The material is expected to swell 14% when excavated from the natural state to lose state it swells to 14%. So, this will help you with the conversion, say for example from the bank unit weight, I wanted to convert it into loosen unit right I can use this swell percentage to make the estimation.

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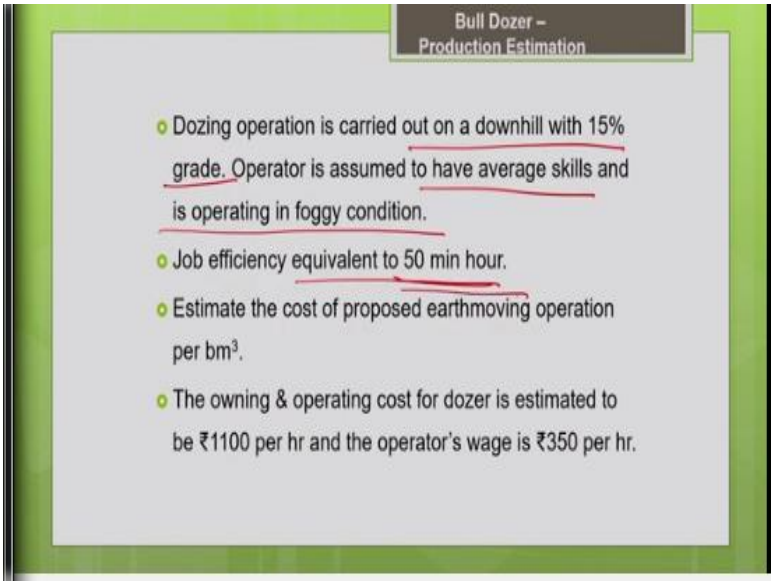

Dozing operation is carried out on a downhill, so with a 15% grade. So, your machine is moving down the slope, so this is obviously going to help you in enhancement of the productivity the operator is assumed to have average skill, not excellent skill, he is just having average skill. And it is our machine is operated in foggy condition, so it means a visibility is going to be poor. And the job efficiency is given is 15 minutes hour, that means the machine is working for 15 minutes in one hour.

You are going to estimate the unit cost of the earthmoving operation. So, before moving further, so let us try to recollect what we learnt earlier. So, in this we are going to make use of the production curves supplied by the manufacturer for the particular model.

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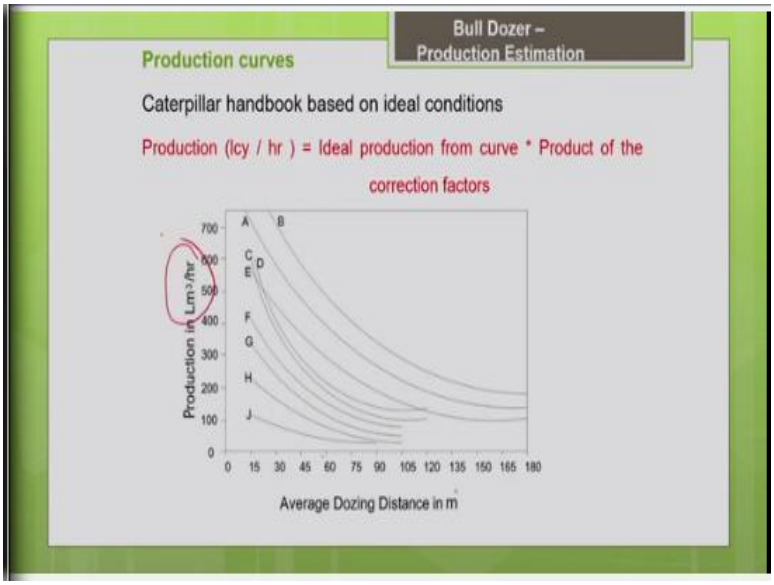

I hope you remember the sample of production curves which I have shown you earlier. So, if you know that dozing distance I can find the production curves. So, in this case the dozing distance is given as 60 meters. So, corresponding to your dozing distance if you know the model you can calculate the productivity. So, these curves are just some sample curves.

So, the actual curves you are supposed to be given you from the equipment handbook. I am just showing some trend of the variation of the productivity with dozing distance. It just shows an approximate representation, the actual values you can get from the equipment handbook. So, corresponding to 60-meter dozing distance what is the productivity for the actual model you have to take it. And the productivity we will get it in loose meter cube per hour.

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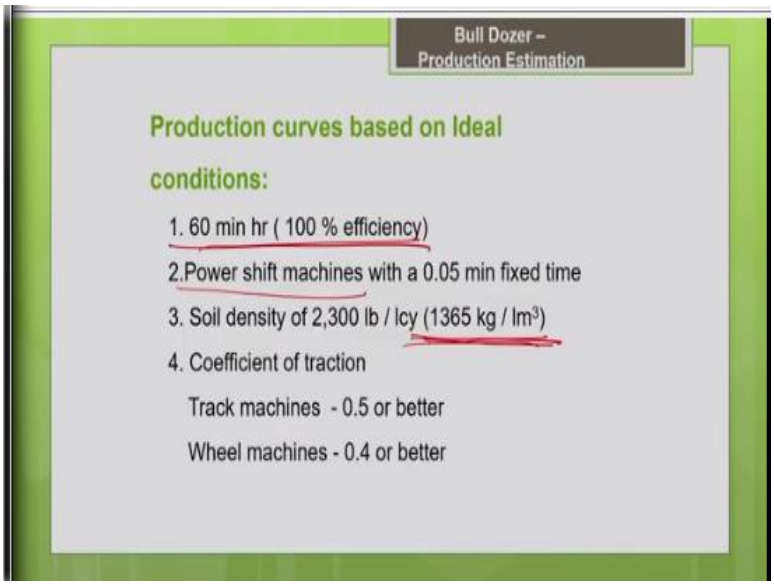

And hope you remember these curves are valid only for these ideal conditions. So, 60 minutes hour but in your project in this problem we found that the machine is working for 50 minutes an hour. So, you are supposed to apply the job efficiency, you have to apply the correction factor accordingly. So, this curve is applicable for power shift mode, automatic usage. So, in this problem also you have the automatic gear change, so no need to apply the correction factor.

But this curve value is applicable for a soil density of 1365 kg per meter cube. So, in our case the soil density is given us 1750 kg per meter cube in bank state that is to be noted the soil the bulldozer is going to do is of density 1750 kg per meter cube in bank state that is to be noted. But the curve, the production value what you have chosen from the curve corresponds to the productivity of 1365 kg loose meter cube. So, we need to compare both this material, now apply a correction factor accordingly.

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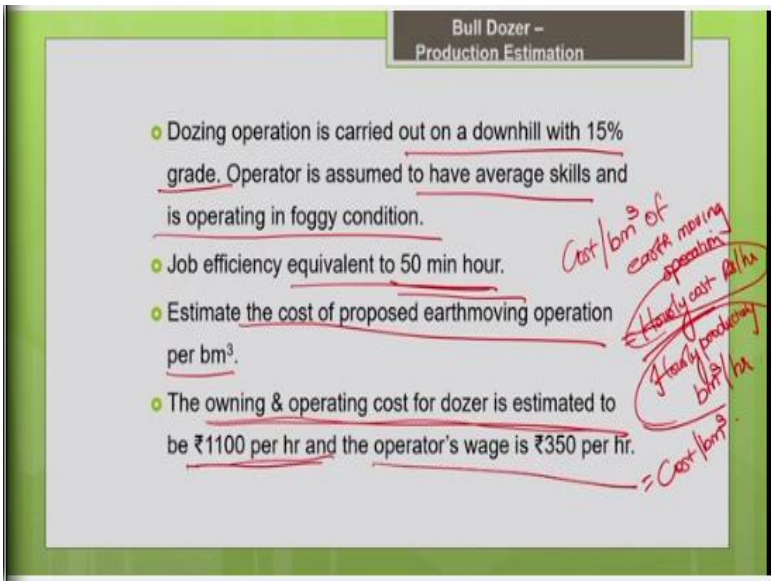

Then other things like operator the curve was drawn for excellent operator skill. So, in our problem the operator skill is average. So, accordingly you have to choose the correction factor and apply. So, your correction factor is going to be less than 1, because it is average is going to reduce your productivity. Similarly, the material type, material type is non-cohesive silty sand, so that will definitely reduce the productivity.

So, the correction factor is going to be less than 1. Slot dozing, you have a lot of slot dozing method in your problem, so that means that will help to increase productivity. So, your correction factor is going to be greater than 1, visibility is poor in the problem what we have discussed. So, that will reduce your correction factor, the productivity will reduce obviously we are working for 50 minutes an hour, so accordingly the correction factor should be applied.

So, in this problem we are moving down the hill, so the grade percentage is -15%. So, accordingly you have to choose the curve supply by the manufacturer. So, corresponding to what is -15% you have to find the correction factor. Obviously, I told you it maybe, so this is 0, the ideal curve is drawn for level terrain, so the grade percentage may go like this. So, what is corresponding to -15% you have to choose approximately.

So, what is the value corresponding to -15%. So, these are just representative trends, you have to get the actual value from the equipment handbook. So, what is the value corresponding to -15%

you can take it approximately. So, that will give you the correction factor, obviously in this case the correction factor is going to be greater than 1, because it is going to enhance the productivity.

So, you are going to choose all the appropriate correction factors from the equipment handbook for this particular project condition. And you have to choose the productivity value for the corresponding model and the corresponding dozing distance from the production curve supplied by the manufacturer. So, if you know both these values we can do this problem. So, after you estimate the productivity you are asked to estimate the unit cost of proposed earthmoving operation per bank meter cube.

That means, cost per bank meter cube of earthmoving operation, you are going to find it. So, that is nothing but your hourly cost associated with the machine divided by the hourly productivity. If you know both these values, this you have to calculate in the bank meter cube per hour. So, if you know both these things I can get what is cost per bank meter cube, unit cost of production.

So, which is the very important parameter, which we use when you plan for a bidding. So, when you go for unit rate contracts, you need to know what is the unit cost associated with every activity. We need to make accurate estimation of the unit cost of every activity. So, for that you need the information on the cost associated with the machine and the productivity associated with the machine, that also forms a part of the unit cost.

So, the cost data is given to you directly, already you know in the previous lectures we have seen worked out, we have seen how to estimate the cost associated with the various machines. Like what are all the ownership cost and the operating cost we have worked out for the equipment. So, using this methodology, you can find the owning and the operating cost of the dozer. In this problem it is given to you directly as rupees 1100 per hour and the operative wage is given as rupees 350 per hour.

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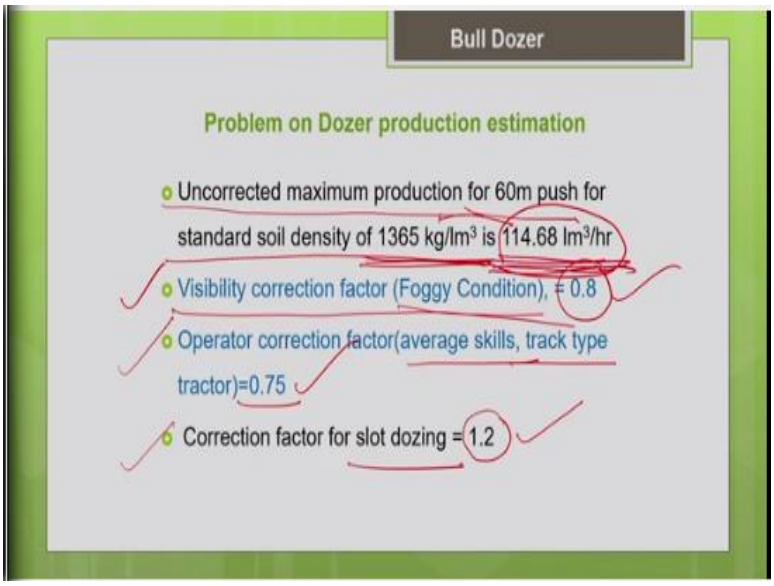

Let us workout the solution for this problem. As I told you the first step is we need to find the uncorrected maximum production for the 60-meter push distance for the standard soil density of 1365 kg per meter cube. So, how will you find the production? So, using the production curves as I told you using this production curve for your model and for the dozing distance, what is the value we can take it, this is called as the uncorrected value.

So, this uncorrected value according to your project conditions, you need to correct it. So, first I am going to choose this value from the curve supplied by the manufacturer. So, that value is found to be 114.68 loose meter cube per hour, this value I am going to adjust according to my project conditions. So, next is and you should note that this is valid for the soil density of 1365 kg per loose meter cube, but in your project the soil density is different.

So, it is given 1750 kg per meter cubic bank state, so you have to adjust it accordingly**.** Now the next is visibility correction factor. So, in this problem it is given foggy condition by the ideal curve is for the excellent visibility. So, you have to apply the correction factor it is found from the manufacturer is 0.8, so I have given you the value directly. Operator correction, here the operator skill is average and for the track mounted machine, the correction factor is going to be 0.75, if the operator skill is excellent, you need not apply correction factor.

Then slot dozing, in this problem you have adopted slot dozing. So, from dozing method perspective, this is even better than the ideal curve value. So, here you can see correction factor is 1.2 because this is going to enhance your productivity greater than 1.

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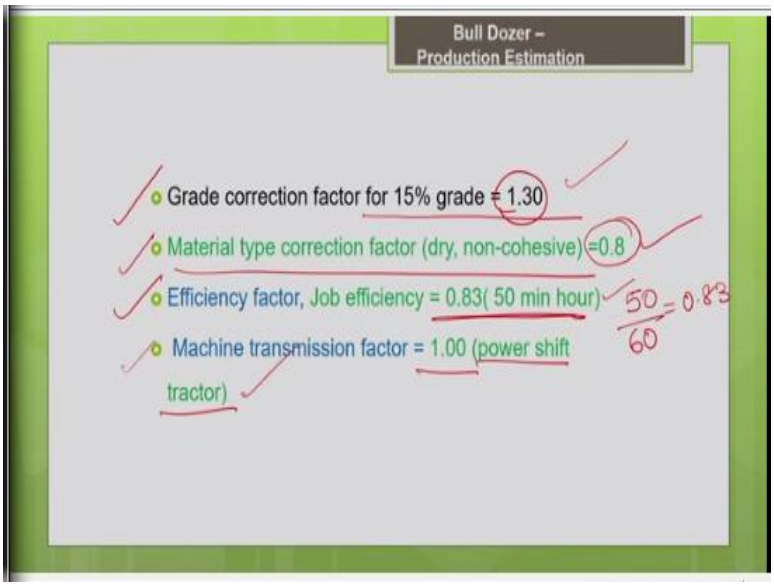

Grade correction, you are moving down the slope -15%. So, your correction factor increases, it is going to enhance the productivity. So, from grade perspective, it is better than the value taken from the ideal curve. Then material type, here it is non-cohesive silty sand, so obviously it will affect the productivity correction factor is less than 1, 0.8. Job efficiency, machine is working for 50 minutes in a hour, so accordingly 50 divided by 60, find the correction factor it is 0.83.

But ideal curve was based on 60 minutes in an hour. So, job efficiency was 1 for the ideal curve, you have to apply according to your project condition, you have to correct it according to your project condition. Then machine transmission factor, so in this problem also it is automatic gear change, power shift mode, so you need not apply any correction factor, so it is just 1, it is same as the ideal condition. In an ideal condition also, it is power shift mode, here also it is power shift mode.

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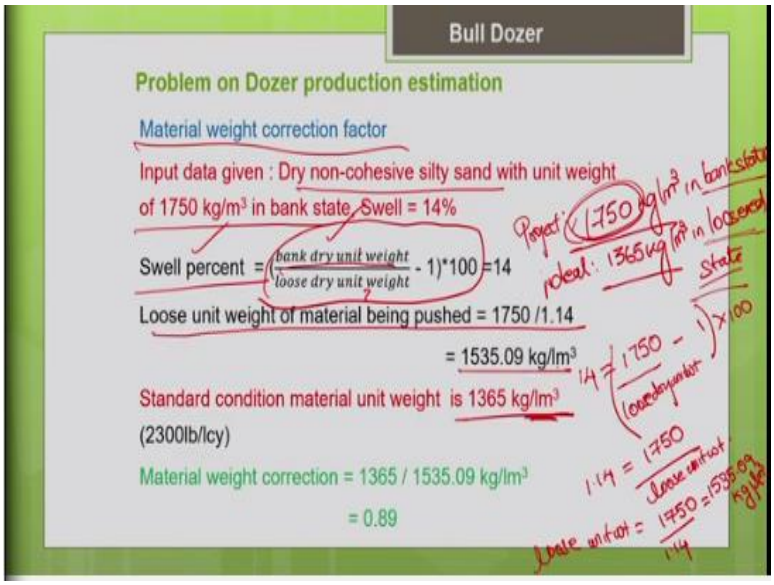

Now another important correction factor which we are yet to determine is material weight correction factor. As I told you in this project we are going to deal with non-cohesive silty sand**.** It is unit weight is given as 1750 kg per meter cube in bank state; it is 1750 kg per meter cube in bank state, so this is your actual project. But the curve value what we have chosen, productivity value what we chosen is for the ideal condition where the soil density is 1365 kg per meter cube.

So, it is in loosen state, loose meter cube, so it is in loosen state. So, I need to compare both, so that we can apply the correction factor. So, we can compare both only when the volume is the same type of measure, but one volume is in bank state other volume is expressed in loosen state So, let me convert this bank state into loosen state, so that I can compare it. So, how to convert the bank density into loosen density?

I can make use of the swell percentage value given, so you can see when the conversion. Swell percentage is nothing but bank dry unit rate divided by loose dry unit weight -1 into 100, that gives as swell percent. So, from the bank state, how much it has expanded to loosen state? That is what is swell percent. So, when you excavate the soil from the natural state when it gets loosened how much it swells or expands that is what is swell present.

So, that is what it is given as 14%. Now, let us convert the bank dry unit rate into loose dry unit rate. So, you know bank dry unit weight and you know the swell percent what is unknown is loose

dry unit weight. Swell percent is 14 equals to bank dry unit weight is 1750 kg per meter cube divided by loose dry unit weight -1 into 100. So, you can move this to left hand side.

$$\textbf{Swell Percent} = \left(\frac{\textbf{bank dry unit weight}}{\textbf{loose dry unit weight}} - \mathbf{1}\right) \times \mathbf{100} = \mathbf{14}$$

$$\left(\frac{\mathbf{1750}}{\textbf{loose dry unit weight}} - \mathbf{1}\right) \times \mathbf{100} = \mathbf{14}$$

loose unit weight of material being pushed = 1750/1.14 = 1535.09 kg/lm^3

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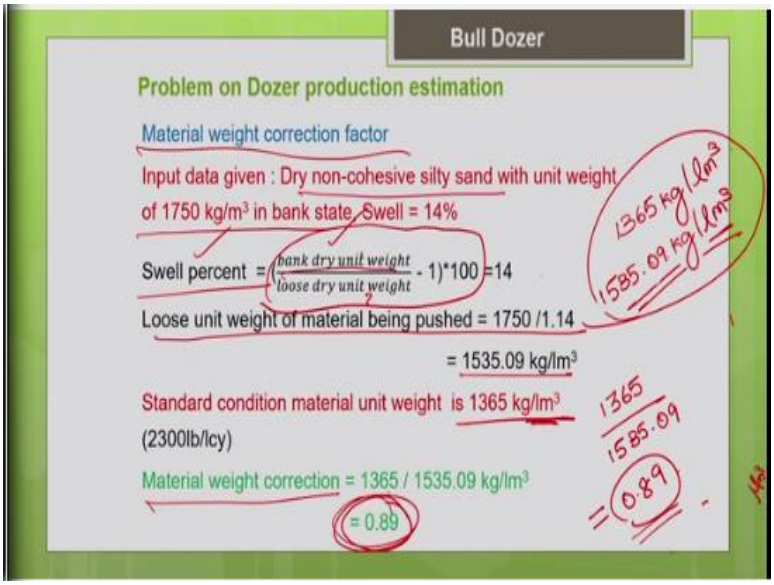

So, now you can compare both, your standard condition is 1365 kg per loose meter cube. So, now your project condition is 1,535.09, per loose meter cube. So, obviously your project soil is more denser than compared to the standard condition curve. So, that means, this is going to affect your productivity when the soil is more denser, it is going to be difficult for the bulldozer to push it. So, that is definitely going to reduce the productivity.

So, you will not be able to realize your productivity as represented by the ideal curve. So, you have to adjust it according to the material weight correction factor. So, how to find the material weight correction factor? It is nothing but 1365 divided by 1,535.09. So, that gives me the material correction factor as 0.89. Obviously, it is also less than 1; it is going to reduce my productivity. So, this is your material weight correction factor.

$$\textbf{Material weight correction} = \frac{\mathbf{1365}}{\mathbf{1535.09}} = \mathbf{0.89}$$

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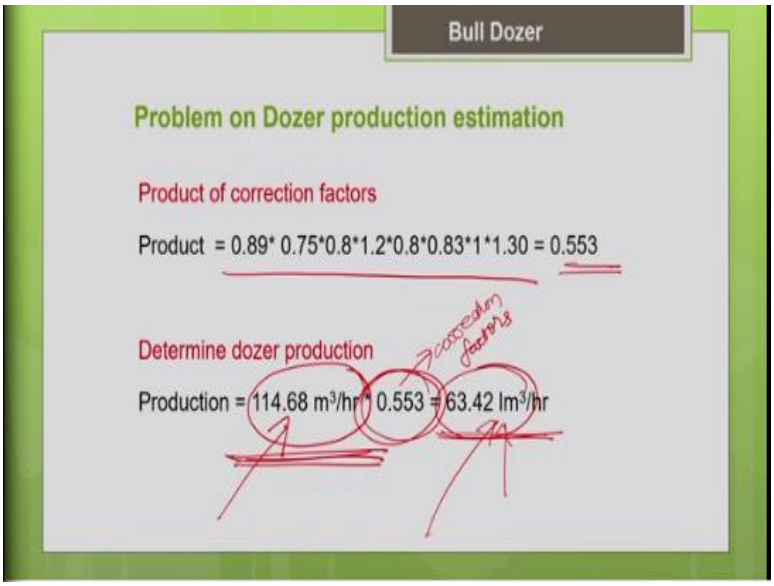

Now let us find the product of all the correction factors. So, whatever correction factors we have discussed so far, let me summarize. So, one is your visibility correction factor 0.8, operator skill correction factor 0.75, correction factor for slot dozing 1.2, grade 1.3, material type 0.8**,** material type connection is different from material weight. Job efficiency 0.83, machine transmission, here we need not because both the cases it is only power shift factor.

Product of correction factors = $\mathbf{0.89 \times 0.75 \times 0.8 \times 1.2 \times 0.8 \times 0.83 \times 1 \times 1.3 = 0.553}$

So, it is just 1 and material weight correction factor is 0.89, so these are all the correction factors. You find the product of all the correction factors you will get the answer as 0.553. So, this is the value you have taken from the ideal curve, hope you remember from the ideal curve, so from the actual medical supplied by the manufacturer. So, I have taken the value as 114.68 loose meter cube per hour.

So, this 114.68 loose meter cube per hour, I am adjusting according to my project conditions by applying these correction factors. That gives the corrected productivity value as 63.42 loose meter cube per hour. So, hope you understand. So, for the ideal condition the productivity is very high but when you adjust it according to your project condition, you can see that the productivity got reduce significantly 63.42 loose meter per hour.

Production = $\mathbf{114. \times 0.553 = 0.553}$ **lm³/hr**

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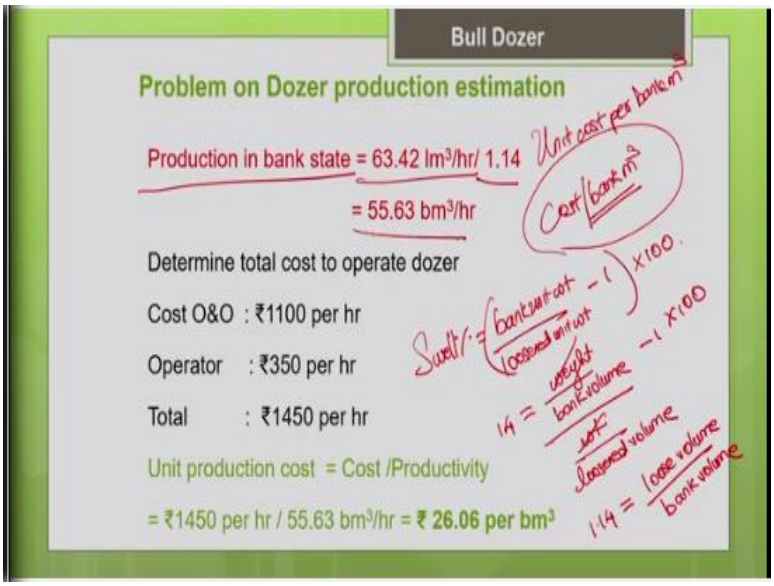

Now the next part, after estimating the productivity, now we are supposed to estimate the unit cost of production, unit cost stop earthmoving operation. So, how to do that, and they asked you to calculate unit cost per bank meter cube. So, that is what is asked in the problem cost per bank meter cube we have to calculate that. So, we need bank meter cube, but what we have calculated so far is your loosened volume.

So, what you know is the information in the loosen state. So, now we have to convert this loosen state value I mean loosen measure again into the bank measure. So, then only we can estimate the cost per bank meter cube. So, the same swell percentage formula you can use for the conversion.

$$\textbf{Swell Percent} = \left(\frac{\textit{bank dry unit weight}}{\textit{loose dry unit weight}} - 1\right) \times 100 = 14$$

And one more thing is, so here it is in volume loose meter cube but the formula is in unit weight, density. So, it is nothing but weight by volume, weight by bank volume. So, weight is going to be same for both the cases only the volume volumetric measure is different weight by loosen volume. So, weight is going to be same can cancel it -1 into 100. So, if we move this to the left hand side 14 divided by 100 + 1, so that is nothing but 1.14 equal to lose volume divided by bank volume.

$$\textbf{1.14} = \frac{\textit{loose volume}}{\textit{bank volume}}$$

$$\textbf{Production in bank state} = \frac{\textbf{63.42 lm3/hr}}{\textbf{1.14}} = \textbf{55.63 bm}^{\textbf{3}}\textbf{/hr}$$

So, now you can calculate, so I need to calculate now bank volume. So, bank volume is nothing, but production in bank state is nothing but the loosen productivity divided by 1.1 that is it. So, you need to calculate bank state, so it is nothing but bring it this. So, it is nothing but bank state productivity is nothing but loosen productivity divided be 1.14. So, that gives you 55.63 the bank meter cube per hour. So, now you know the hourly productivity in bank state your estimated, so you need to know the hourly cost. So, how to calculate the cost?

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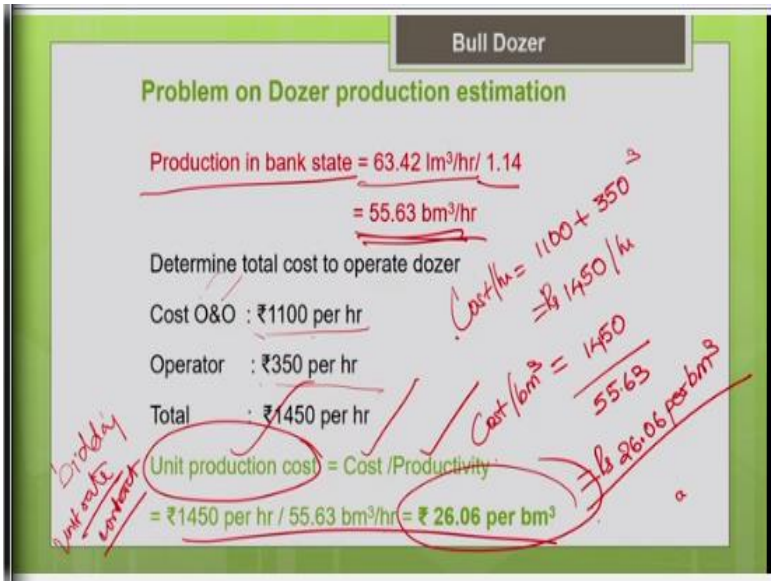

Already it is given to you the ownership and the operating cost is 1100 per hour, operator cost is given. So, cost per hour = 1100 + 350 rupees, so that gives you 1450 rupees per hour is the hourly cost. So, now let me calculate the cost per bank meter cube, it is nothing but the hourly cost by hourly productivity. So, 1450 divided by hourly productivity is 55.63, so this gives me the answer as rupees 26.06 per bank meter cube.

So, this is how you calculate the unit production cost. So, this is a very important parameters as I told you when you plan for your bidding. So, when you plan for your bidding when you go from unit rate contract, so in the unit rate price what you quote this part will also over a component of that. So, that is why you have to be very careful in the estimation of the unit production cost.

For that you need to have a thorough knowledge on how to estimate the cost associated with the machine and the productivity associated with the machine, then only you can make an accurate estimate of the unit cost of production.

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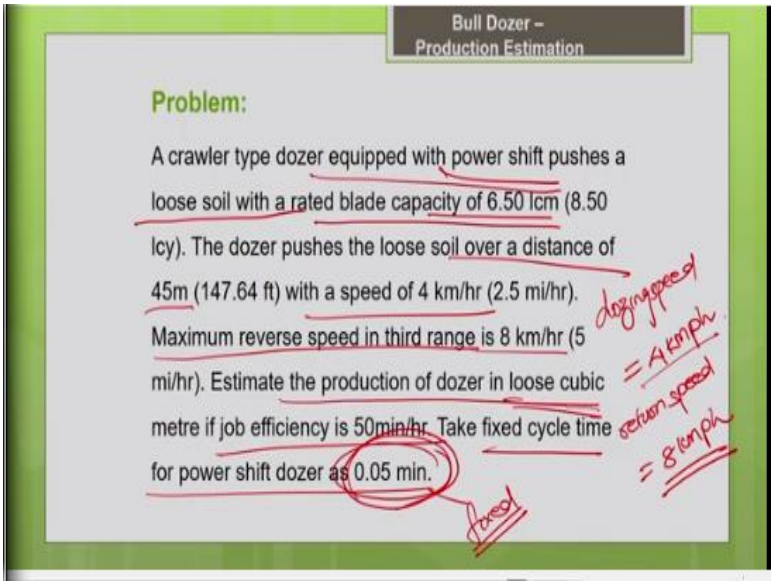

Now let us workout another problem a different approach of estimation of the productivity. So, in this a crawler type bulldozer is given, this equipped with power shift mode. So, automatic gear change, it pushes a loose soil with blade capacity 6.5 loose cubic meter. So, the blade capacity is given to you 6.5 loose cubic meter, and the dozer pushes the loose soil over a distance of 45 meters.

So, the dozing distance is given as 45 meter and dozing speed is given as 4 km per hour and maximum reverse speed in the third range is 8 kilometer per hour. So, mostly since a bulldozer is operated for short distances, so the return journey it will be mostly operated in the reverse gear. So, the return speed has given as 8 kilometer per hour.

Obviously, the return speed will be greater than the dozing speed because the blade is unloaded or empty, so it has to be greater. Now estimate production of the bulldozer in loose cubic meter, if the job efficiency is 50 minute per hour. So, since it is a power shift mode, you can assume the fixed cycle time for the power shift dozer as 0.5 minute. So, the maneuver time when you go for automatic gear change machines is 0.05 minute, you can assume that. So, that will be your fixed

cycle time, this is your fixed cycle time. So, now, we are going to estimate the productivity of the bulldozer, so with the available input data. So, how to estimate it?

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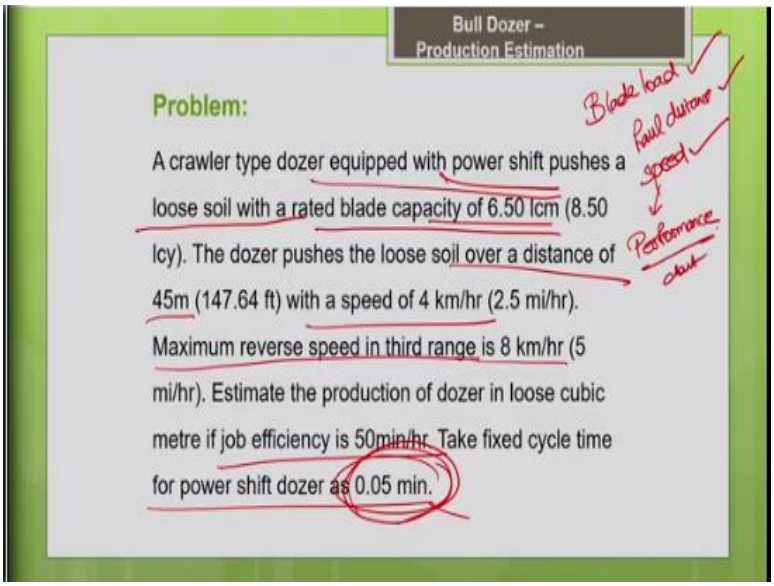

So, you know the blade capacity, you know the blade load, that is known. So, you know the haul distance the dozing distance is known, so it is known, you know the speed of the machine. If the speed is not given in that case you have to go for the performance chart, with the help of performance chart you have to find the speed. But in this problem speed is given to you directly.

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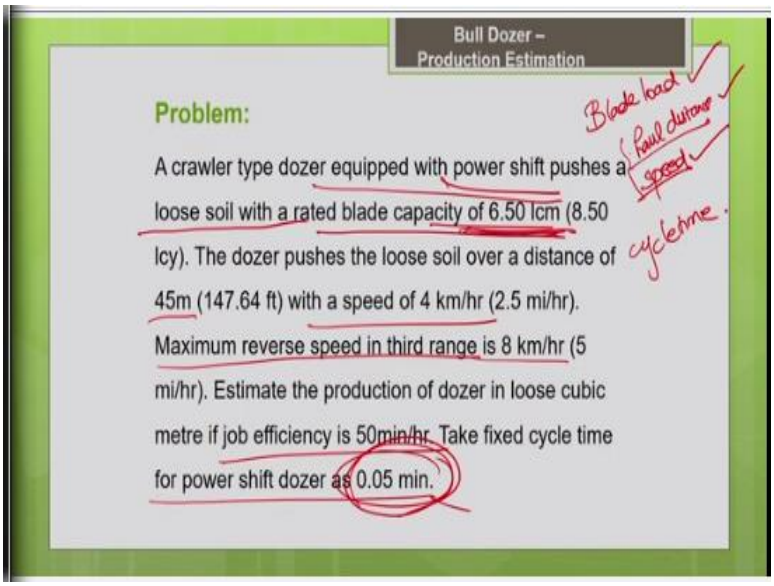

So, you know the haul distance and speed, so you can calculate the cycle time. So, based on using this input parameters, I can estimate the productivity of the bulldozer. So, let us see how it is done.

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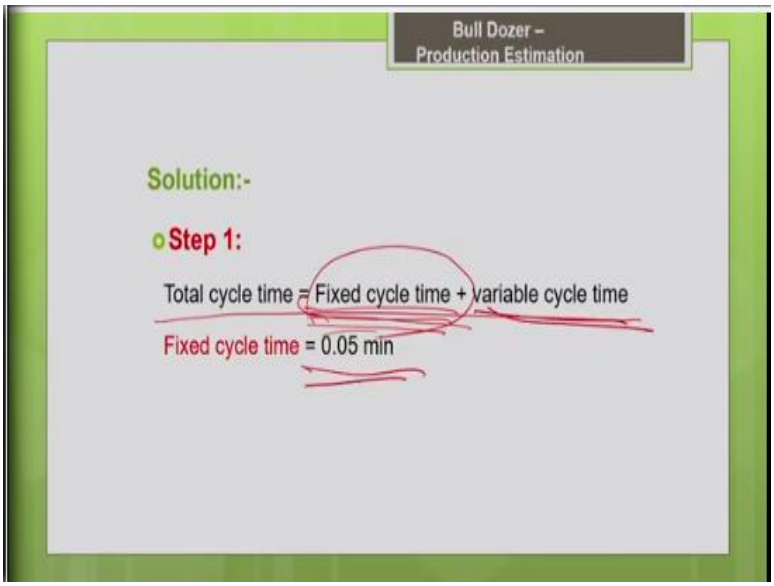

So, first the total cycle time is nothing but fixed cycle time plus variable cycle time. So, the time needed for cutting and pushing the earth and the returning back. So, the return time plus the maneuver time, your maneuver time is nothing but fixed cycle time, maneuver is nothing but time for changing the gears, increasing the speed or decreasing the speed. So, those things come into the maneuver time, for this power shift mode it can be taken as 0.05 minute. So, now we have to estimate the variable cycle time. So, that depends upon your haul distance and the speed.

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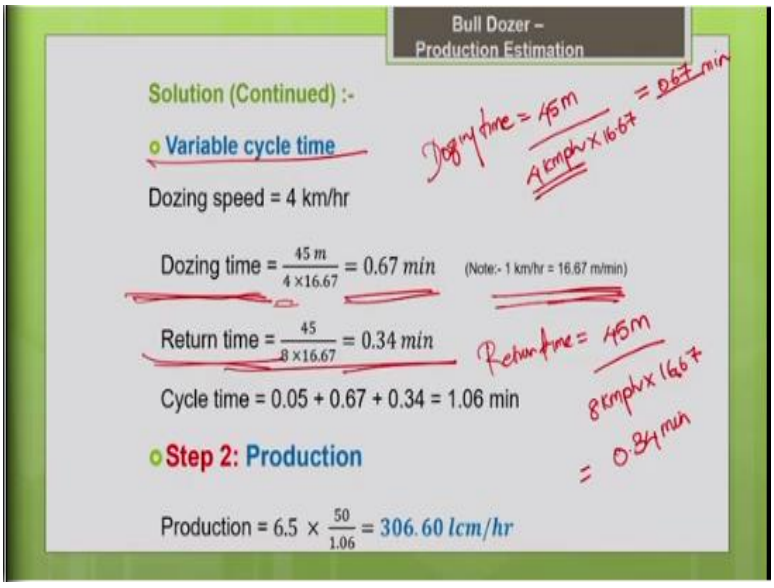

So, variable cycle time is nothing but it is made up of dozing time and the return time, onward journey, return journey. So, dozing time you know the dozing distance 45 meter and the speed is

given 4 kilometer per hour. So, let me convert, so let me find the dozing time, so the distance is given as 45 meter and the speed is given as 4 kilometer per hour. So, let me convert this kilometer per hour into meter per minute**,** the conversion factor is 16.67, 1 kilometer per hour is 16.67 meter per minute.

$$\textbf{Dozing time} = \frac{45m}{4 \times 16.67} = 0.67min$$

$$\textbf{Return time} = \frac{45m}{8 \times 16.67} = 0.34min$$

So, you return time is 0.34 minute, dozing time is 0.67 minute. So, now your total cycle time is supposed to calculate.

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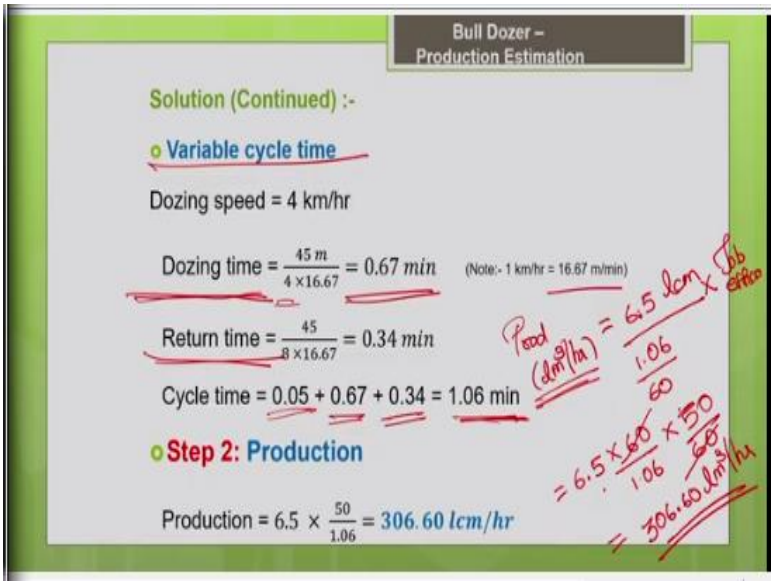

Total cycle time is nothing but your maneuver time,

Cycle time = 0.05+0.67+0.34 = 1.06min

that is your cycle time. Now you calculate the productivity, I need a productivity and loose meter cube per hour, so how to calculate that? I know the blade load, so the blade load was given to you as 6.5 loose cubic meter.

So, use this value 6.5 loose cubic meter divided by the total cycle time is 1.06 minute. So, I need the answer in loose meter cube per hour. So, let me convert this minute into hour, divided by 60, 1.06 divided by 60. And one more important thing you have to multiply it by the job efficiency. So, you are going to work for how much time in a hour that is job efficiency, working efficiency 6.5 divided by let me simplify 6.5 into 60 divided by 1.06.

So, what is the job efficiency? It is nothing but it works for 50 minutes in a hour, it is given in the question like the job efficiency is 50 minutes per hour, so it is 50 by 60. So, you can get the answer as 306.60 loose meter cube per hour,

$$\textbf{Production} = 6.5 \times \frac{50}{1.06} = 306.60 \text{lcm/hr}$$

So, this is your final productivity. So, this is one way of estimation, so depending upon the input data accordingly you can choose the approach.

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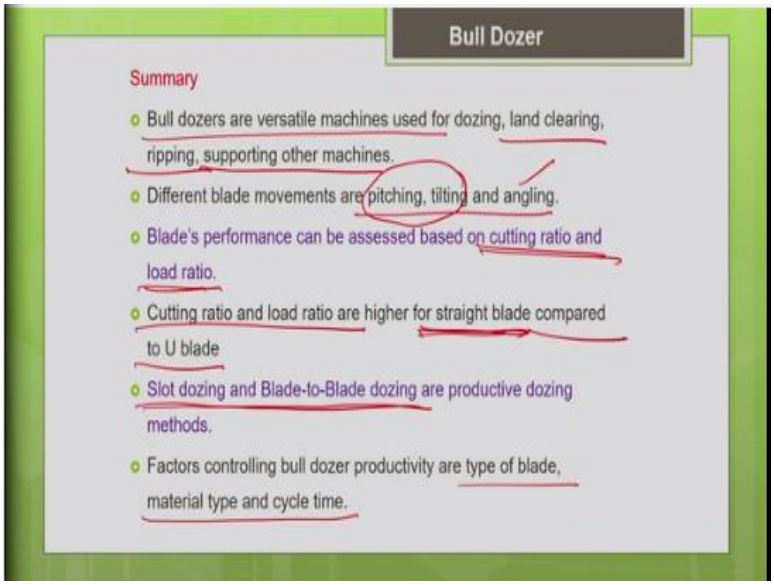

So, now we have come to the end of the lecture on bulldozer. So, let me summarize what we have discussed so far. So, as you know that bulldozers are versatile machines, so because it is used for different applications. So, not only for the earthmoving operations, we can also use it for cutting the trees, ripping the rocks and for assisting other machines. So, it is used for n number of applications, so that is why we called as a versatile machine.

So, and we saw that depending upon the type of connection between the blade and the tractor, we can have different types of blade movements pitching, tilting and angling. So, if you have a C frame, then angling is possible, angling and tilting is possible. So, if you have tilt cylinder and pusher arm arrangement, in that case only pitching and tilting were possible, angling would not be possible.

So, according to the type of connections, the blade movements will vary. And you can assess the performance of the blade using the parameters like cutting ratio and load ratio. And we discuss that with the dimension of the blade is smaller the cutting ratio and load ratio will be higher. So, for the straight plate as it is smaller, it is higher the cutting ratio and load ratio is higher when compared to the U blade.

And other important thing is we have also seen what are all the different productive dozing methods which are adopted to reduces it is spillage, end spillage, slot dozing and blade to blade dozing**.** This can help you to increase the productivity of the earthmoving operation. And we have discussed about what are all the factors which affect bulldozer productivity, like the type of the plate, material type and cycle time. And we have worked out illustrations of how to estimate the productivity of the bulldozer using different approaches based upon the input data available.

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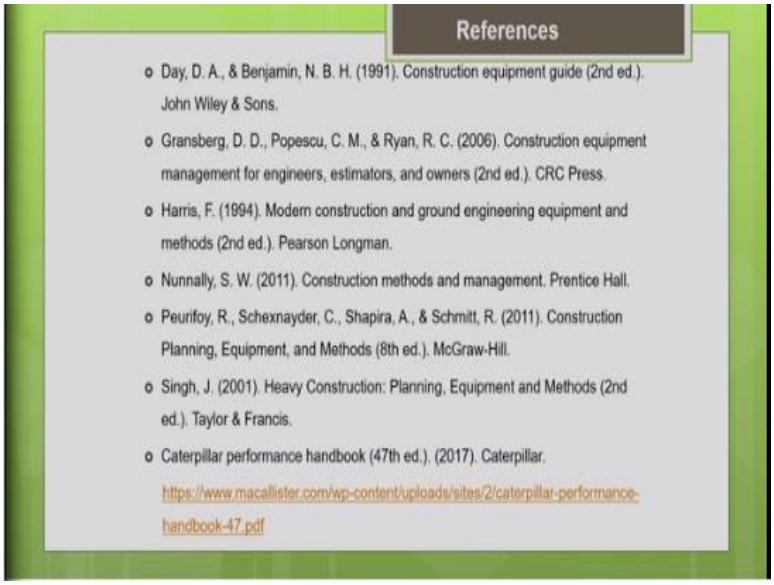

So, these are the references which I have used for the preparation of this lecture. You can go through some of these textbooks to get more information related to this topic. In the next lecture, we will be discussing about the scrapers. So, scraper is also another earthmoving machine. So, we will be discussing about the different types of scrapers, applications and illustrations and how to estimate the productivity of the scrapers, thank you.