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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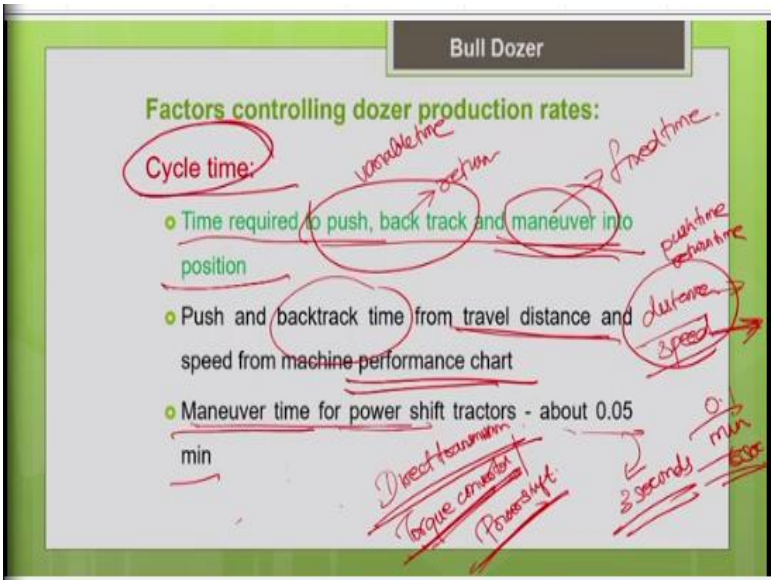

One is either you can have direct transmission or you can have this torque converter mode or power shift. Direct transmission is nothing but manual gear change. So, the operator has to manually change the gear depending upon the load conditions. Here the torque converter it will automatically match the 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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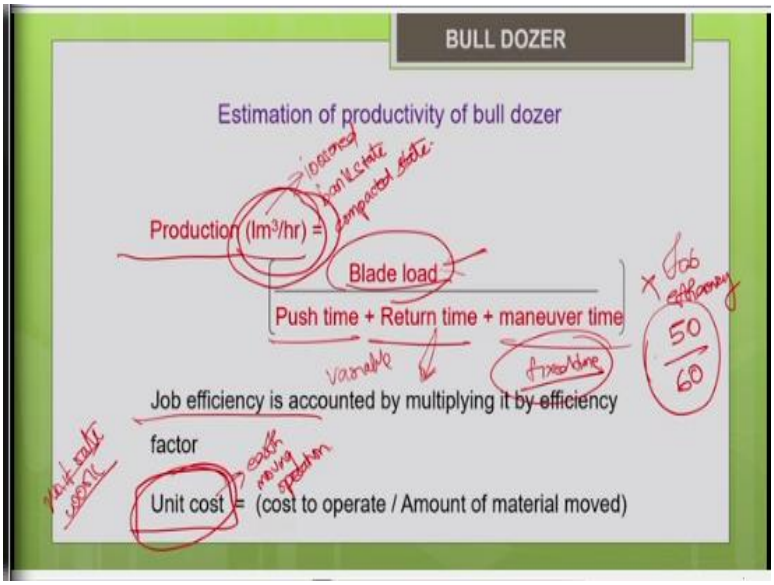

Now let us see how to estimate the productivity of the bulldozer. So, we are going to estimate the productivity a lose meter cube per hour. As I told you whenever you express the volume, you should be very specific that whether you are expressing the volume in the loosen state or bank state, that is 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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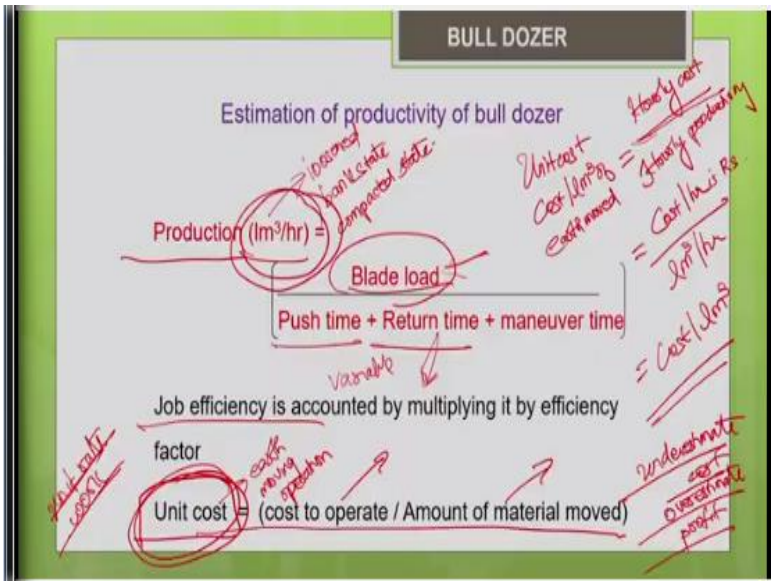

So, for that you need to know unit cost is nothing but cost per loose meter cube. Say I am going to find it in the loosen state cost per meter cube of earth moved, I need to calculate. It is nothing but your hourly cost associated with the machine divided by the hourly productivity. If we know these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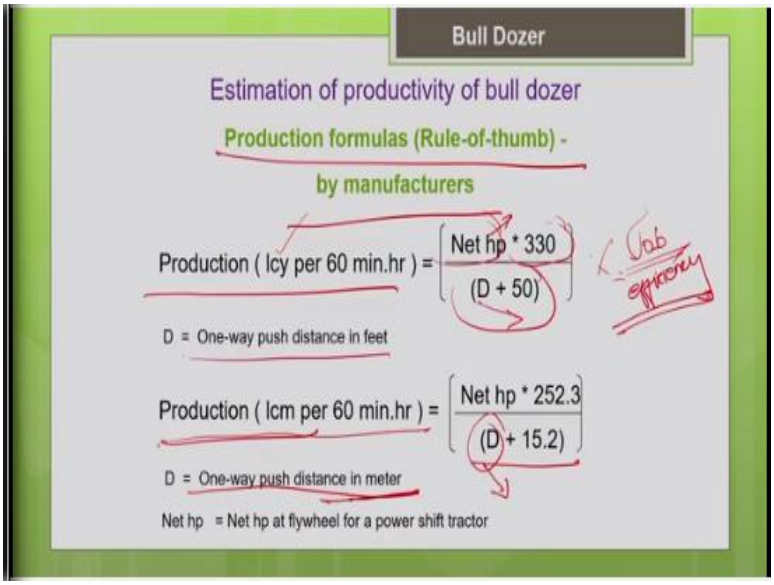

So, there are some thumb rules available provided with a equipment manufacturers. So, if you know the horsepower of the tractor and if you know the dozing distance, one-way push distance you can directly estimate the productivity of the bulldozer, these are thumb rules. It is nothing but your say net 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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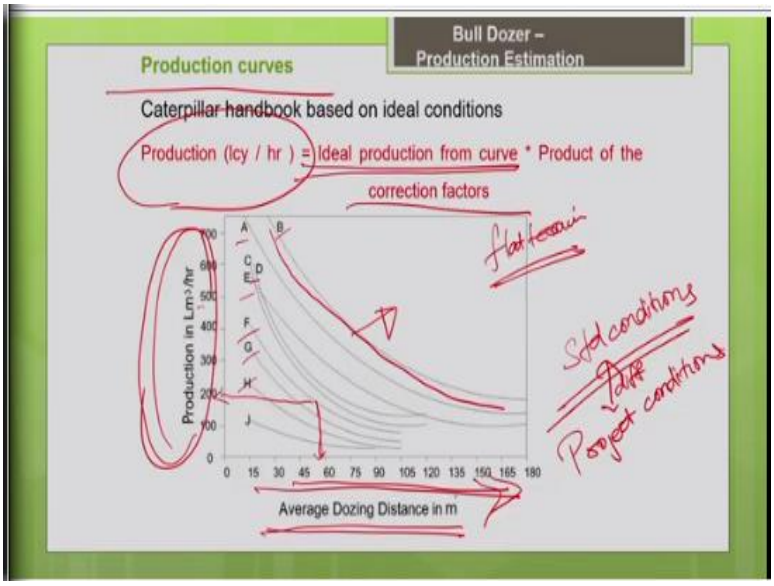

So, there is also another approach to determine the productivity. So, with the help of production curves, say some of the equipment manufacturers they do supply these production curves for the different models which they have manufactured. So, from this production curves, this just show some sample curves 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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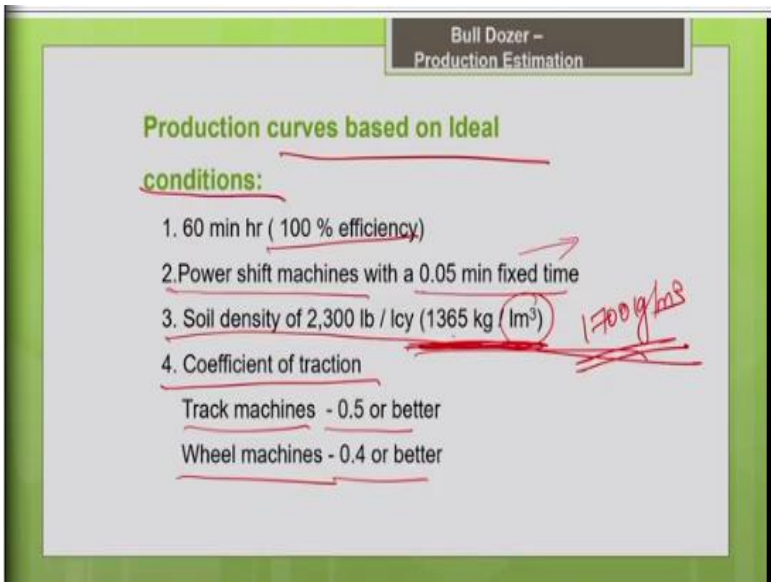

So, as I told you these production curves are drawn based upon ideal conditions. What are all ideal conditions? It is drawn assuming 100% job efficiency, that means your machine is going to work for 60 minutes in a hour, so that is what is the assumption. But in your real project site, your machine will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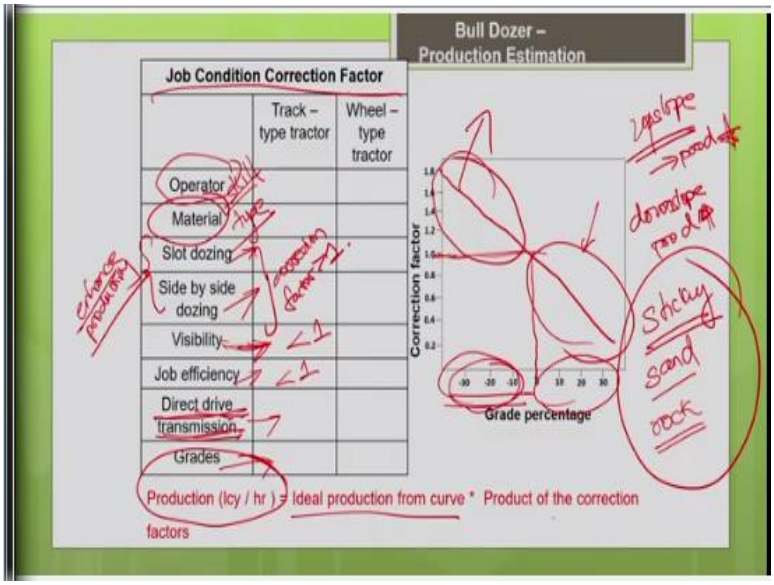

I am just giving you a broad guideline, you have to refer to the either the equipment handbook or the appropriate textbook as I mentioned by Peurifoy et al. So, that you can get these values you can come to know about these values. So, this table shows you what are all the correction factors which are 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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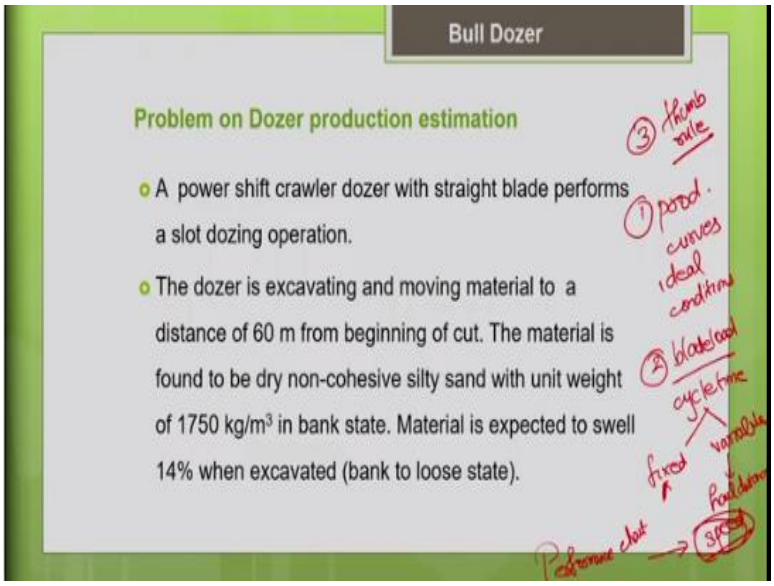

So, using production curves, which are drawn for the ideal conditions? So, we choose the value from the corresponding production curve which is supplied by the manufacturer. And apply the correction factors according to the project conditions and find the actual productivity for the project conditions, 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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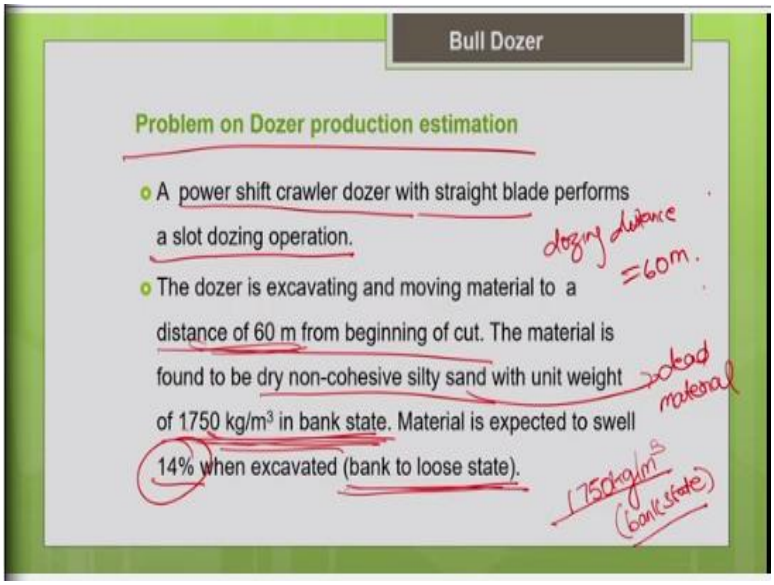

In this problem we are going to estimate the productivity of this power shift crawler dozer. So, power shift, so it is automatic gear change, so you can assume the maneuver time. The dozer is with a straight blade, it performs a slot dozing operation. The slot dozing operation you know that we adopt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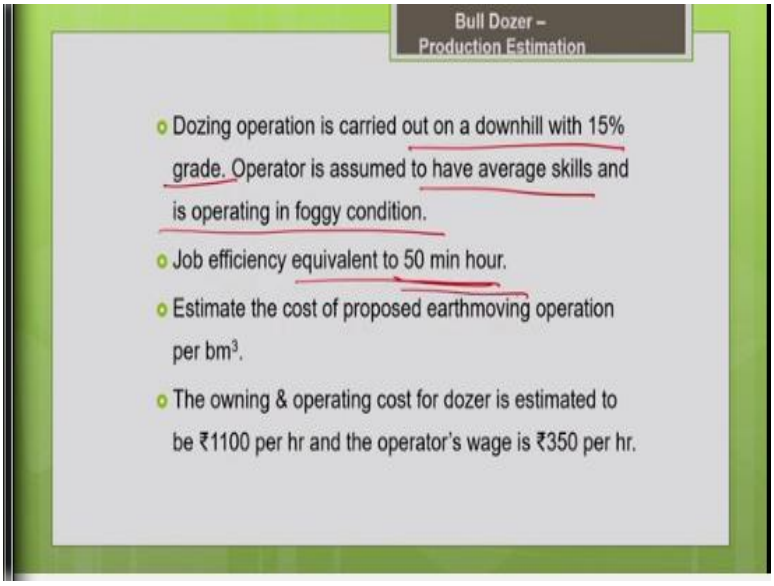

Dozing operation is carried out on a downhill, so with a 15% grade. So, your machine is moving down the slope, so this is obviously going to help you in enhancement of the productivity the operator is assumed to have average skill, not excellent skill, he is just having average skill. And it is our machine 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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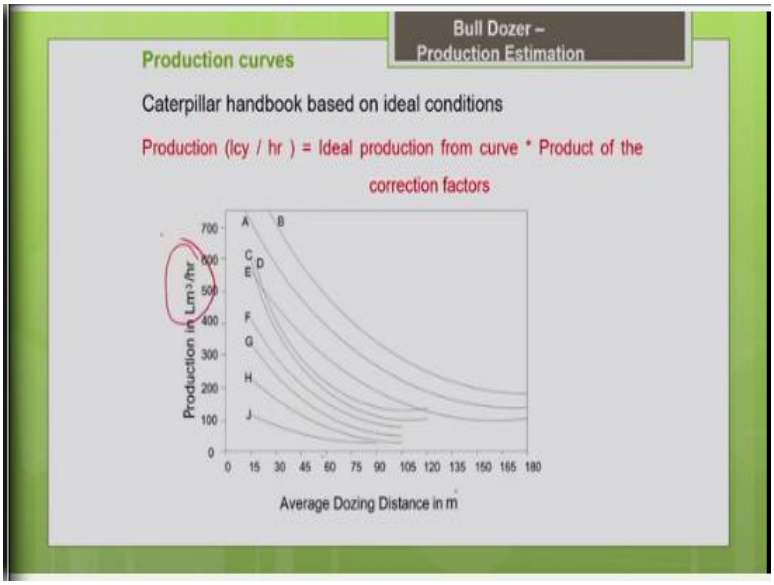

I hope you remember the sample of production curves which I have shown you earlier. So, if you know that dozing distance I can find the production curves. So, in this case the dozing distance is given as 60 meters. So, corresponding to your dozing distance if you know the model you can calculate the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