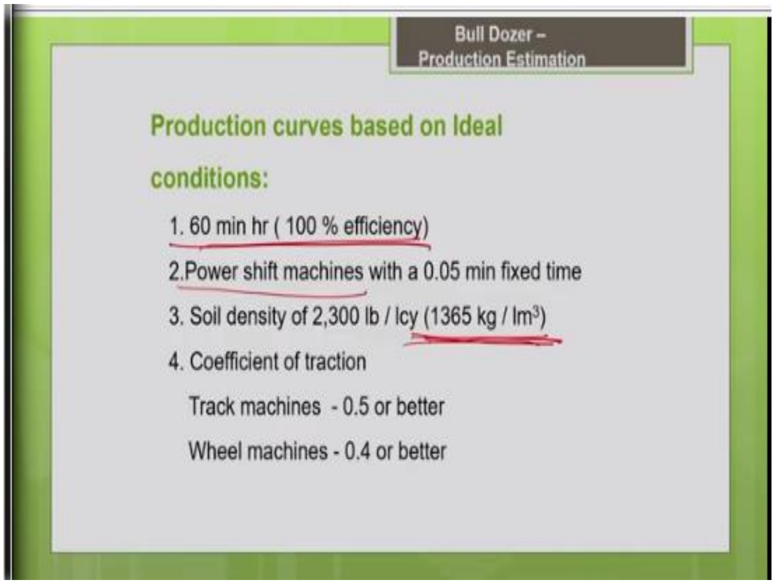

And hope you remember these curves are valid only for these ideal conditions. So, 60 minutes hour but in your project in this problem we found that the machine is working for 50 minutes an hour. So, you are supposed to apply the job efficiency, you have to apply the correction factor accordingly. So, 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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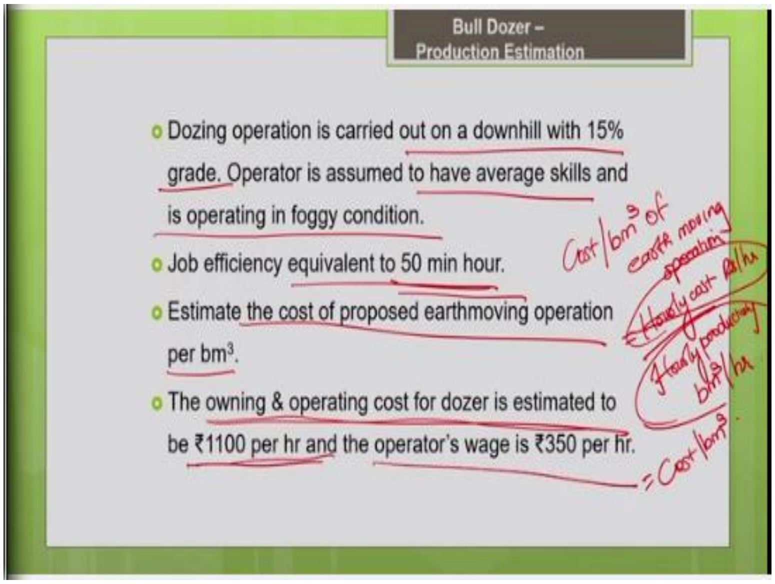

Then other things like operator the curve was drawn for excellent operator skill. So, in our problem the operator skill is average. So, accordingly you have to choose the correction factor and apply. So, your correction factor is going to be less than 1, because it is average is going to reduce your 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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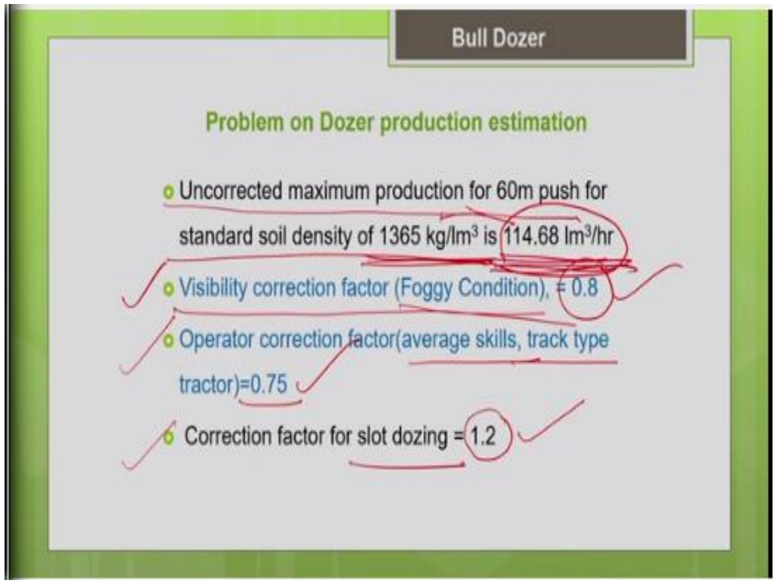

Let us workout the solution for this problem. As I told you the first step is we need to find the uncorrected maximum production for the 60-meter push distance for the standard soil density of 1365 kg per meter cube. So, how will you find the production? So, using the production curves as I told you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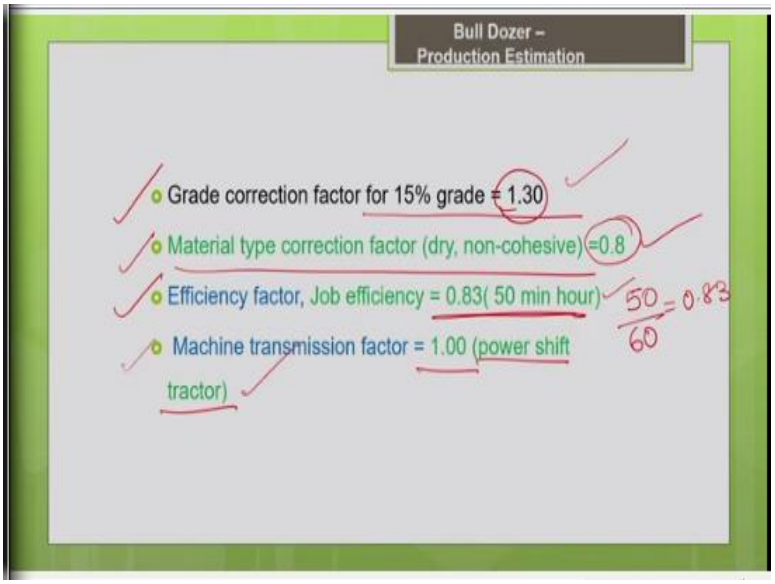

Grade correction, you are moving down the slope -15%. So, your correction factor increases, it is going to enhance the productivity. So, from grade perspective, it is better than the value taken from the ideal curve. Then material type, here it is non-cohesive silty sand, so obviously it will affect 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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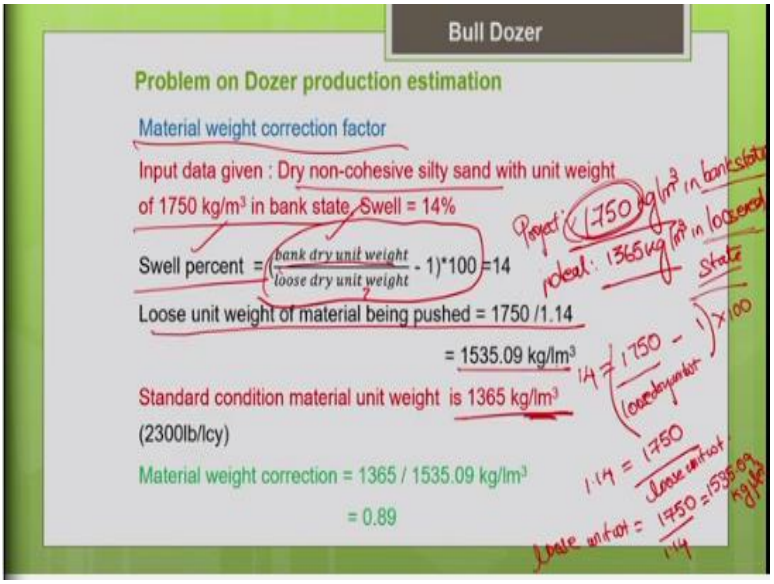

Now another important correction factor which we are yet to determine is material weight correction factor. As I told you in this project we are going to deal with non-cohesive silty sand**.** It is unit weight is given as 1750 kg per meter cube in bank state; it is 1750 kg per meter cube in bank state, 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.

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

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

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

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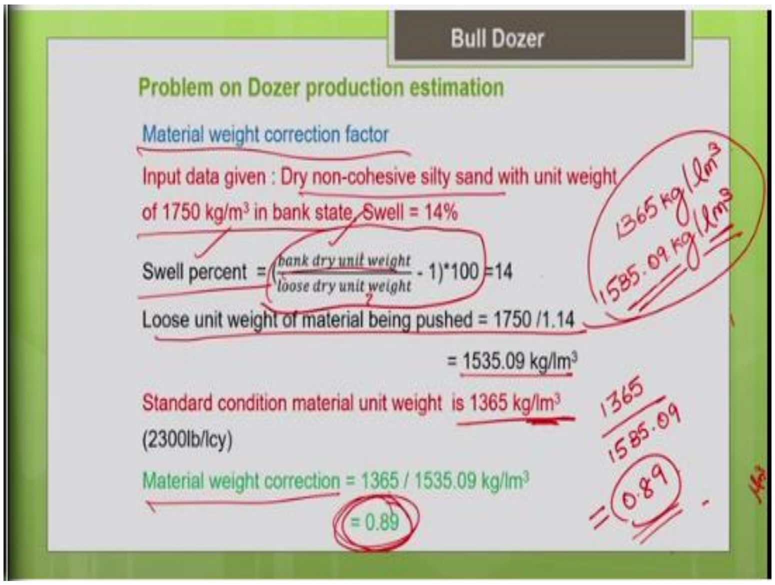

So, now you can compare both, your standard condition is 1365 kg per loose meter cube. So, now your project condition is 1,535.09, per loose meter cube. So, obviously your project soil is more denser than compared to the standard condition curve. So, that means, this is going to affect your productivity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

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

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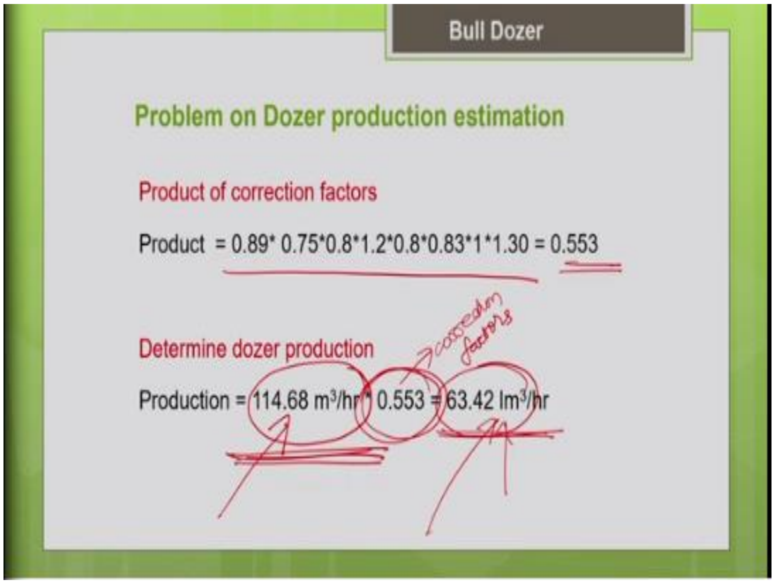

Now let us find the product of all the correction factors. So, whatever correction factors we have discussed so far, let me summarize. So, one is your visibility correction factor 0.8, operator skill correction factor 0.75, correction factor for slot dozing 1.2, grade 1.3, material type 0.8**,** material 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 = $\mathbf{114.\times 0.553 = 0.553}$ **lm**^{3}**/hr**

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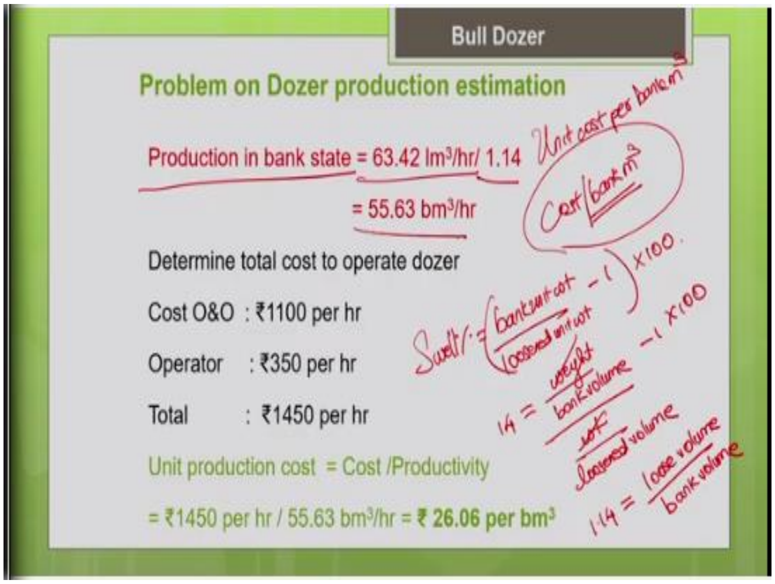

Now the next part, after estimating the productivity, now we are supposed to estimate the unit cost of production, unit cost stop earthmoving operation. So, how to do that, and they asked you to calculate unit cost per bank meter cube. So, that is what is asked in the problem cost per bank meter cube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

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

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.

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

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

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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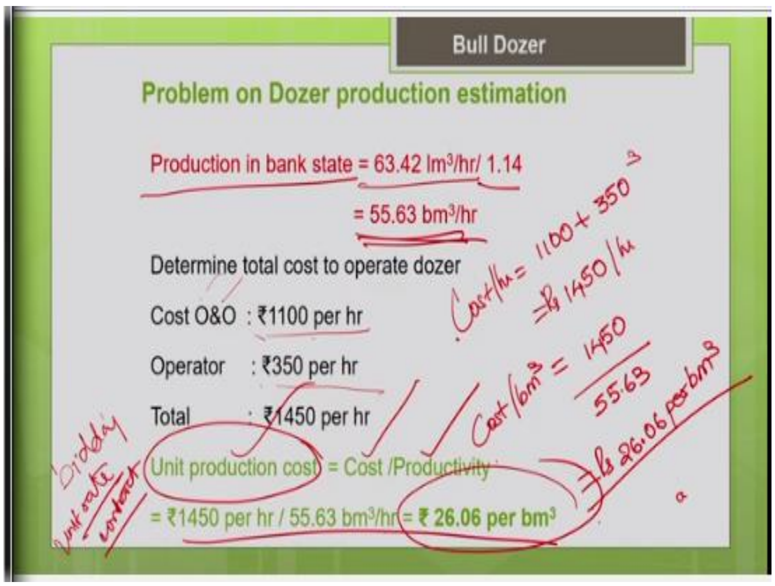

Already it is given to you the ownership and the operating cost is 1100 per hour, operator cost is given. So, cost per hour = 1100 + 350 rupees, so that gives you 1450 rupees per hour is the hourly cost. So, now let me calculate the cost per bank meter cube, it is nothing but the hourly cost by hourly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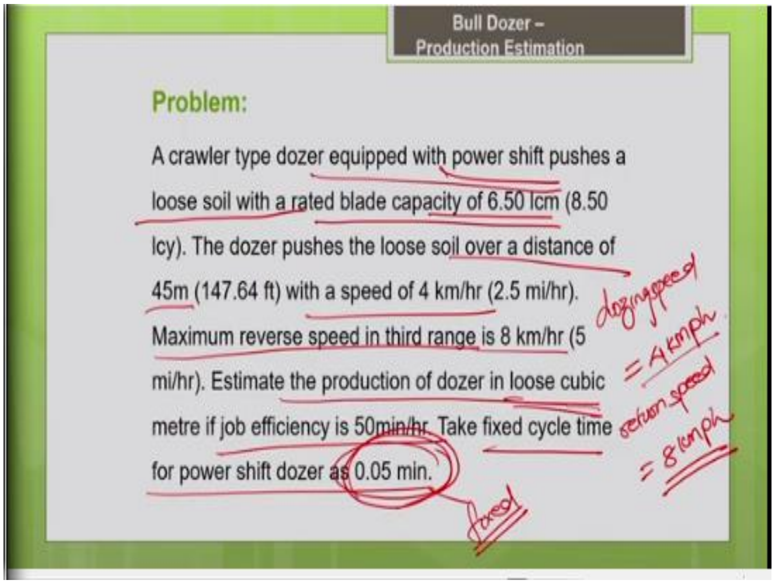

Now let us workout another problem a different approach of estimation of the productivity. So, in this a crawler type bulldozer is given, this equipped with power shift mode. So, automatic gear change, it pushes a loose soil with blade capacity 6.5 loose cubic meter. So, the blade capacity is given to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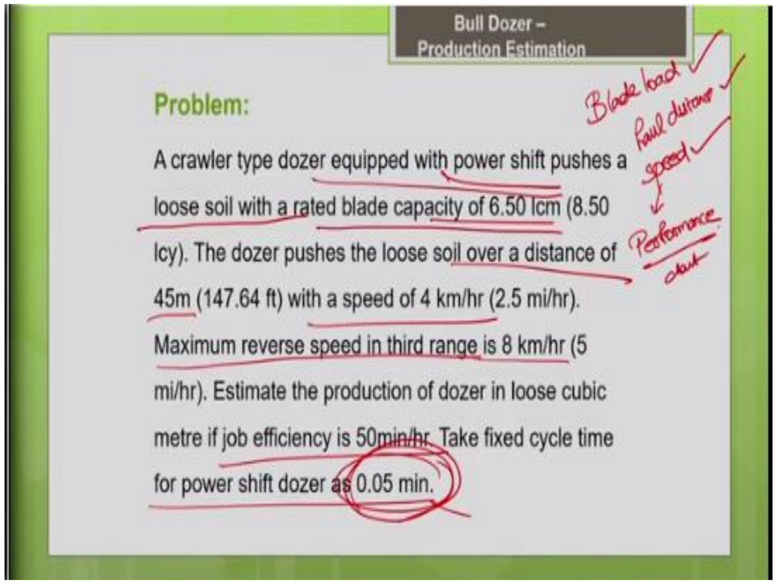

So, you know the blade capacity, you know the blade load, that is known. So, you know the haul distance the dozing distance is known, so it is known, you know the speed of the machine. If the speed is not given in that case you have to go for the performance chart, with the help of performance chart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

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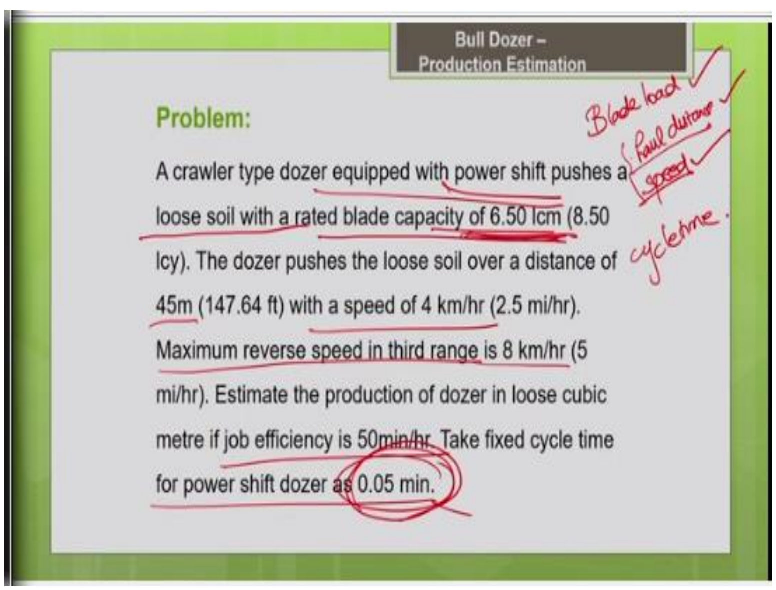

So, you know the haul distance and speed, so you can calculate the cycle time. So, based on using this input parameters, I can estimate the productivity of the bulldozer. So, let us see how it is done.

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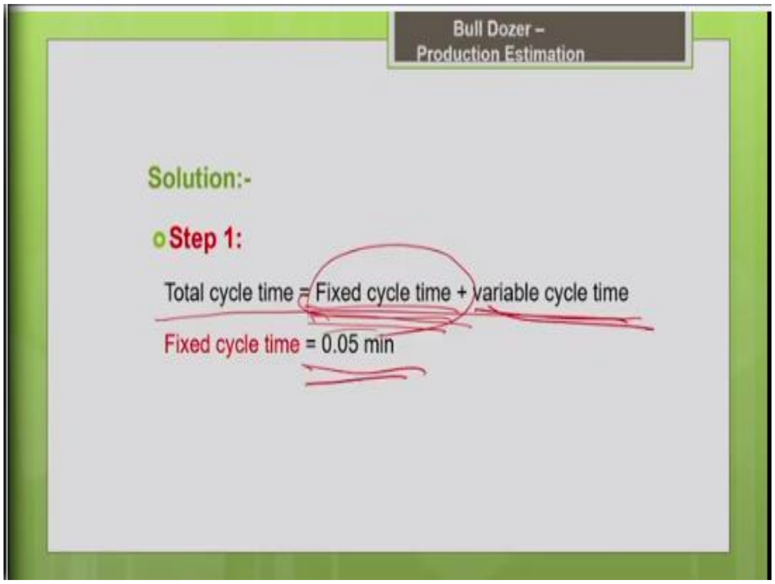

So, first the total cycle time is nothing but fixed cycle time plus variable cycle time. So, the time needed for cutting and pushing the earth and the returning back. So, the return time plus the maneuver time, your maneuver time is nothing but fixed cycle time, maneuver is nothing but time for changing 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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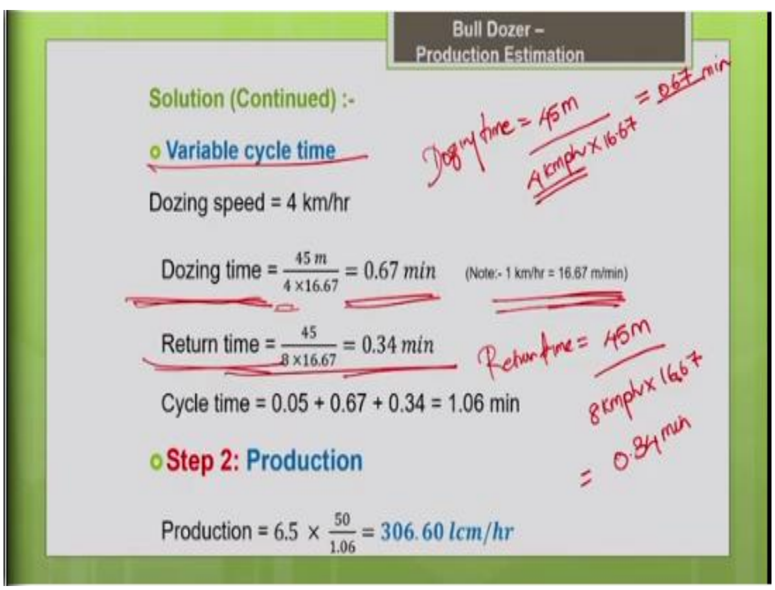

So, variable cycle time is nothing but it is made up of dozing time and the return time, onward journey, return journey. So, dozing time you know the dozing distance 45 meter and the speed is given 4 kilometer per hour. So, let me convert, so let me find the dozing time, so the distance is given as 45 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.

$$\textbf{Dozing time} = \frac{45m}{4\times16.67} = 0.67min$$

$$\textbf{Return time} = \frac{45m}{8\times16.67} = 0.34min$$

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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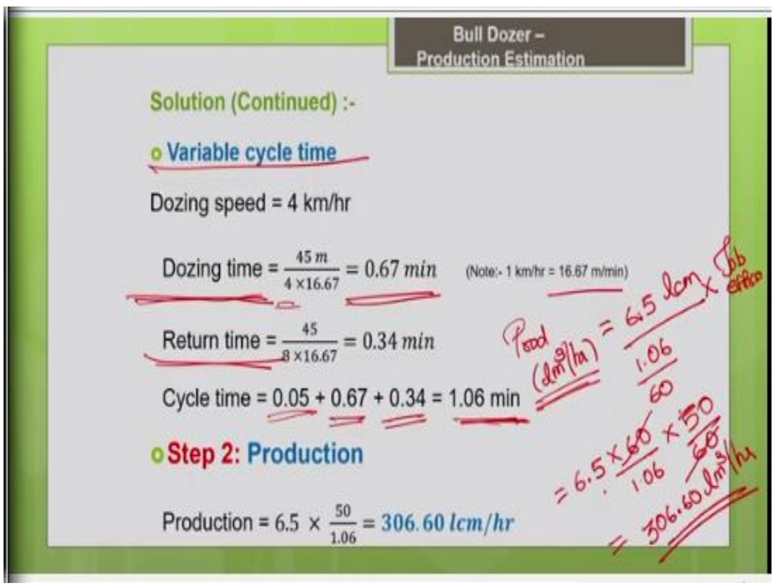

Total cycle time is nothing but your maneuver time,

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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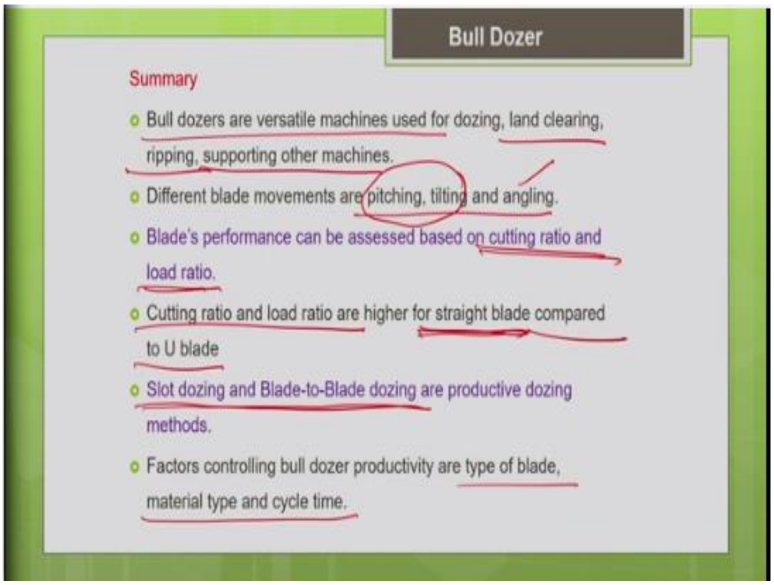

So, now we have come to the end of the lecture on bulldozer. So, let me summarize what we have discussed so far. So, as you know that bulldozers are versatile machines, so because it is used for different applications. So, not only for the earthmoving operations, we can also use it for cutting the trees,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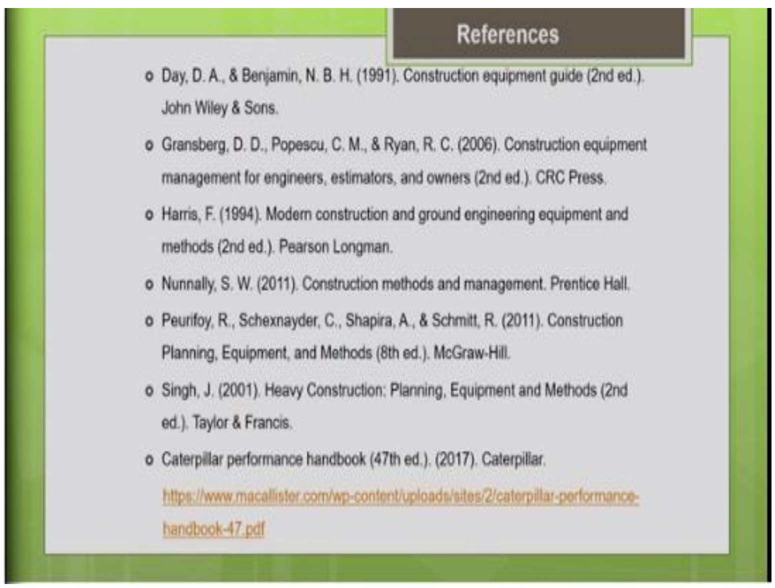

So, these are the references which I have used for the preparation of this lecture. You can go through some of these textbooks to get more information related to this topic. In the next lecture, we will be discussing about the scrapers. So, scraper is also another earthmoving machine. So, we will be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