But the loading time will be number of bucket loads multiplied by the bucket cycle time**.**

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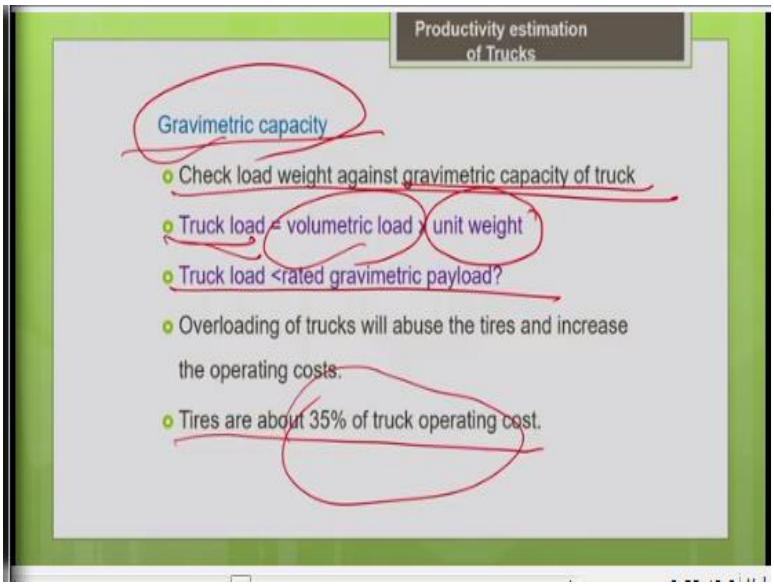

Another important thing you have to keep in mind is, for any machine whatever maybe the mission we have discussed about different types of machines so far. All the machines we are concerned about the safe gravimetric capacity of the machine. For every machine what is this safe operating load in terms of weight is given by the manufacturer, so that we call it as a gravimetric capacity.

So, only that capacity your machine can take because the structural frame of the machine is designed to handle that particular load only. So, we are not supposed to load the machine beyond the gravimetric capacity. So, since the density of material can vary from case to case, it is always advisable to check whether the load weight is within the safe gravimetric capacity. Check the load weight against the gravimetric capacity of the truck, how to check that?

For that you need to know what is the unit weight of your material, if you know the density of your material you can multiplied by the volumetric load you will get the actual weight of material in the truck, you will get the truck load. That should be within the rated gravimetric capacity of the machine given by the manufacturer, check truck load is less than rated gravimetric payload.

See many times you can see that people will put these side boards, and in the trucks commonly you can see they put the side boards and try to increase the volume of the truck. If the material

which you are going to handle is less denser, in that case it will not create much problem, you have to check whether the loaded weight in the truck is within the gravimetric capacity.

But if the material is going to be denser like wet sand or other denser material, what happens is there are more chances that your machine maybe overloaded. That means the weight of material in the truck will be above the safe gravimetric capacity defined by the manufacturer. In that case it will result in lot of wear and tear to the machine**,** so particularly your tires will flex and it will result in abusing of tires**.**

So, you know that for most of the machines the tire cost almost to 35% of the truck operating cost**.** So, if you overload the machine it will result in abusing of tires and it will increase the tire cost significantly. So, this thing you should keep in mind that like by keeping side boards and the keeping overloading the trucks though you are able to increase the productivity for a shorter time.

Those benefits will be only for a shorter time, this is because if you keep on overloading your truck it will result in premature aging of the truck, and it will result in huge loss for you, it will result in yearly replacement of your truck**.** So, you have to replace the truck with a new truck, that will result in huge ownership cost for you**.** So, that is why you should not overload the truck.

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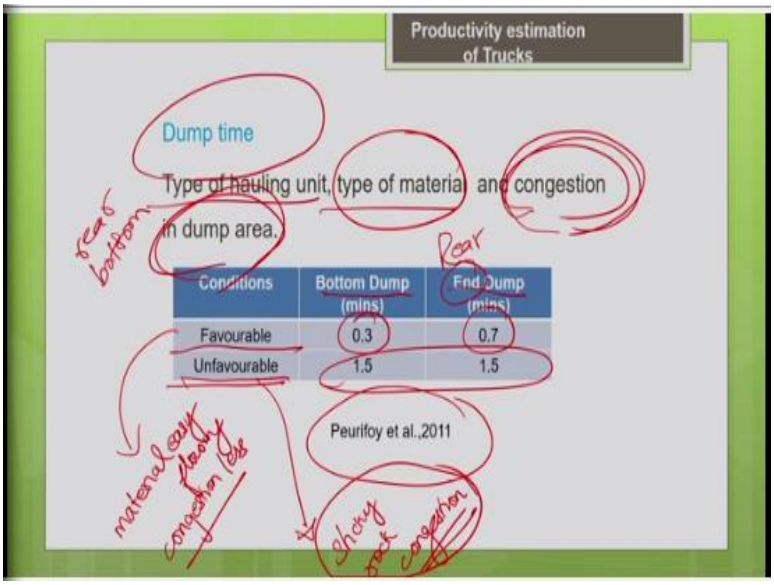

So, next is about the dumping time**.** So, as we discussed earlier the dumping time will depend upon the type of hauling unit whether it is going to be rear dump or it is going to be bottom dump or side dump accordingly the dump time will vary. Whether the material is easy flowing material or sticky material, rock**,** blasted rock**,** all these things will affect your dumping time.

And the congestion in the dumping area, you know that in the construction site, so many equipment will be working parallel. Say for example in the dumping site there may be bulldozers and graders, leveling. So, in that case there may be possibilities of a lot of congestion in the dump area then your machine may have to wait. So, till it to get it is chance for unloading or dumping, so the congestion of the dump area all these things will affect the dump time.

So, that is why these values are taken from the textbook by Peurifoy et al. So, they have given you the time needed for bottom dump truck and end dump truck, end dump is nothing but your rear dump. So, for different types of conditions say they have classified the condition to favorable, unfavorable. Favorable in the sense, say easy flowing material and the congestion in the dump site is less, so all these are favorable conditions**.**

Unfavorable conditions mean, the material is a sticky material or rock as I told you, which is unfavorable. So, in that case there is more congestion in your dump site, so machine has to wait, that is unfavorable condition. So, they have given you the time approximate estimate of time for favorable and unfavorable condition. So, you can compare the bottom dump and rear dump you can find it if the conditions are favorable the bottom dump time is very much less when compared to the rear dump**.**

That is what I told you earlier also when compared to rear dumping your bottom dump time will be relatively lesser, provided the conditions are favorable. But in the unfavorable conditions you can say that both are comparable only bottom dumping and rear dumping. So, if the conditions are favorable it is preferable to go for the choice of bottom dump, so that you can have reduced cycle time and increase productivity.

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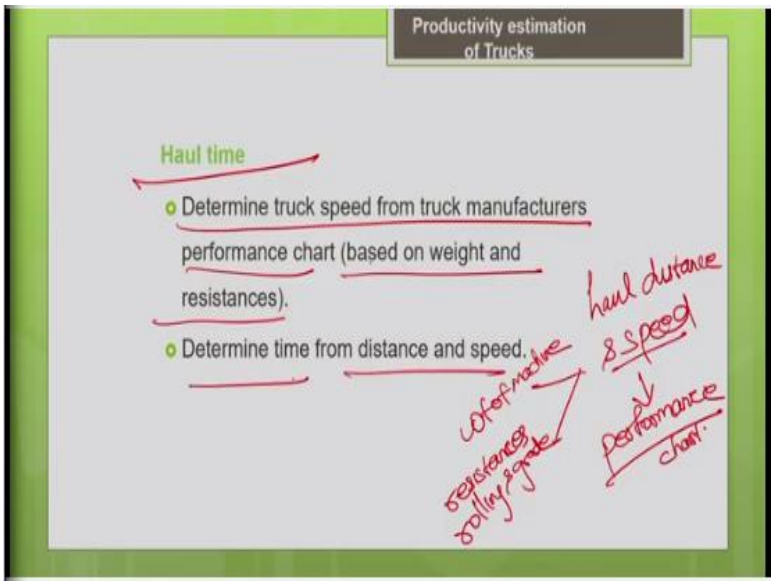

Now next is about the haul time. Haul time it depends upon your haul distance and the speed, speed you can get it from the performance chart. So, to use the performance chart you need to know what is the weight of the machine and also you need to know what are all the resistances in your project site, so the rolling resistance and the grade resistance.

If you know all these input data you can find the speed from the performance chart. So, determine the truck speed from the truck manufacturer performance chart. If you know for that you need to know the weight of the machine and the resistances in your project site. So, once you know the speed and the distance I can calculate the haul time.

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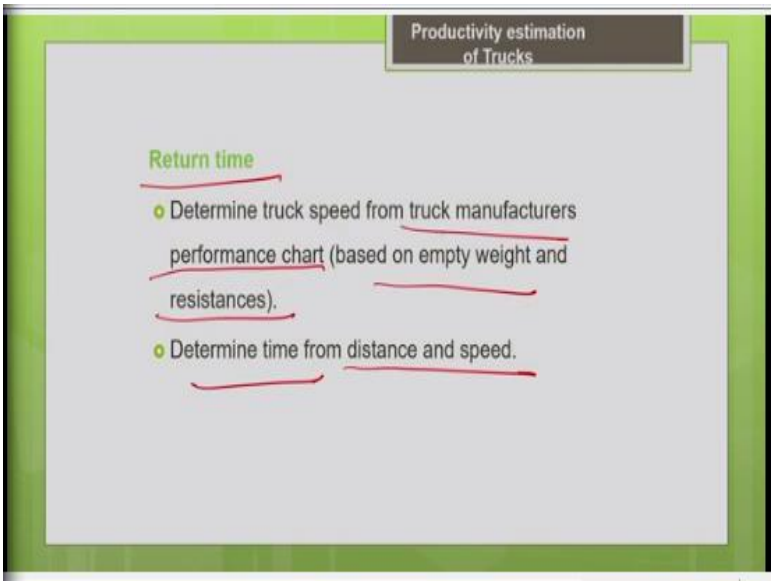

The return time the same way using truck manufacturer performance chart, but here the truck will be in the unloaded condition, empty weight, and consider the resistances also. So, you know the distance and speed I can calculate the return time, obviously the return speed will be more, so the return time will be less as the truck is in the empty condition.

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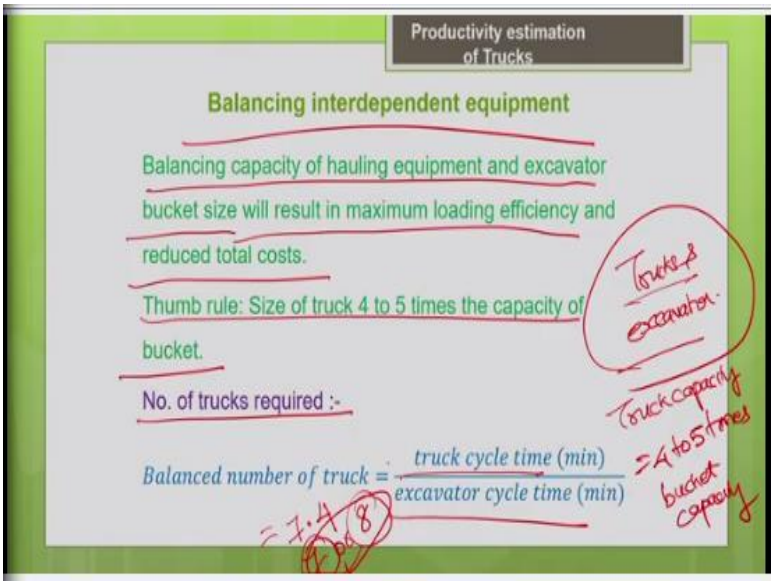

Now let us see how to balance the interdependent machines, trucks and the excavators. I hope you remember earlier we have discussed how to balance the interdependent machines your scraper and the pusher? In a similar manner we are going to discuss how to balance the number of trucks and the excavator? So, balancing is very important, just now we discussed balancing the capacity of the interdependent machines very important.

So, balancing the capacity of the hauling equipment and the excavator bucket size will result in maximum loading efficiency, and reduce total cost. So, that is why I told you based upon the studies they have found that the truck capacity should be 4 to 5 times the bucket capacity that is what is going, this is the thumb rule, size of the truck 4 to 5 times the capacity of the truck that is the ideal case.

So, when they are compatible you can see that the cycle time will be less both will be working at maximum production. Now let us find what is the balanced number of trucks, so how many trucks are going to be served by one excavator, that is what we are going to find. So, that depends upon

the cycle time of your truck and the cycle time of your excavator**.** So, divide the truck cycle time by the excavator cycle time, you will get the balance number of trucks.

So, the balance number indicates a particular number at which both the machines are working at same production level. They will give you the maximum productivity, there would not be much waiting time, so the cycle time will be less the productivity will be maximum**.** It is preferable to go by the balance number**.** But more often you can see that you may not get a whole number.

Say for example I am getting the balance number say 7.4 whether I should round it to 7 or I should round it to 8 trucks, we have to decide, how to decide that? We have to work out the economics, if I go for 7 trucks for 1 loader or 1 excavator. If I go for 8 trucks for 1 excavator, what is the unit production cost associated with that. You consider both the cases and then make a decision, that will be more logical.

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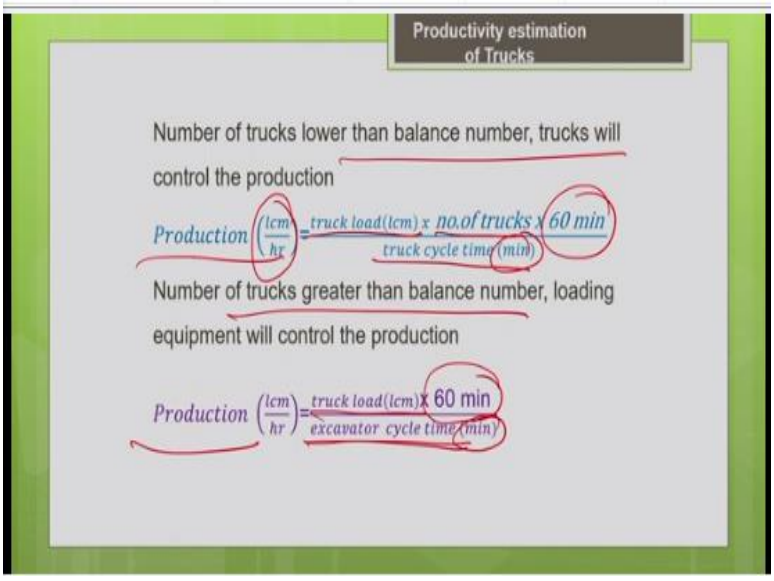

Now let us consider the case say the number of trucks lower than the balance number. Say I am going to round it to lower number, say I got 7.4 now I am going to round it to 7. When I round it to lower than the balanced number that means trucks are less than what is needed. So, trucks are more critical for the production, so here the loader will have the idle time, loader will be waiting for the truck**,** so truck cycle time will control the productivity of this stream**.**

So, the truck productivity will be controlling**,** so production, how to estimate the production in this case? Truck load multiplied by number of trucks divided by the truck cycle time**.** So, here truck cycle time I have taken in minutes, so I am converting it to hour, because I need the productivity loose cubic meter per hour, so I am just multiplying by 60 minutes.

$$\textbf{Production} = \frac{\textbf{truck load} \times \textbf{no.of trucks} \times \textbf{60 min}}{\textbf{truck cycle time}}$$

In the case when I round it to the number greater than the balanced number. So, instead of rounding it to 7, I am rounding it to 8. In this case number of trucks are greater than the balance number, so the trucks will have the idle time, truck will be waiting for the loader, loader will be critical here**.** Beyond the balance number you can see that the productivity will be controlled by the loader cycle time**.**

Unless the loader is available though the trucks are more in number they cannot do the job**.** So, the production is going to be controlled by loader, loader cycle time or excavator whatever excavator cycle time. Now how to estimate the productivity? Truck load divided by the excavator cycle time it is in minutes, so converting into hour I need to multiply by 60 minutes, this will give the production of the system when the number of trucks is greater than the balance number.

If I choose, if we round it to number greater than the balanced number. But very commonly you can see that people prefer to round it to lower than balanced number. One reason is basically when it is lower than the balance number you can engage the excavator or the loader to address the loading site and it will get ready for the next truck. And people also do not prefer working with loader continuously, because if the loader or excavator works continuously and if it breaks down it will severely affect your entire system.

Say for example you have only one excavator and if the excavator breaks down that will hamper your project seriously. But the trucks are more in number even if the truck breaks down, if one truck breaks down it will affect the production but that would not be as serious as the breakdown of a loader or the excavator, that you have to always keep in mind. That is why routine maintenance of the loader or the excavator is very important for the continuous running of the system**.**

That is why people always prefer rounding it to lower number, but the logical way is to work out the economics of both the cases and then take a decision, that will be more logical**.**

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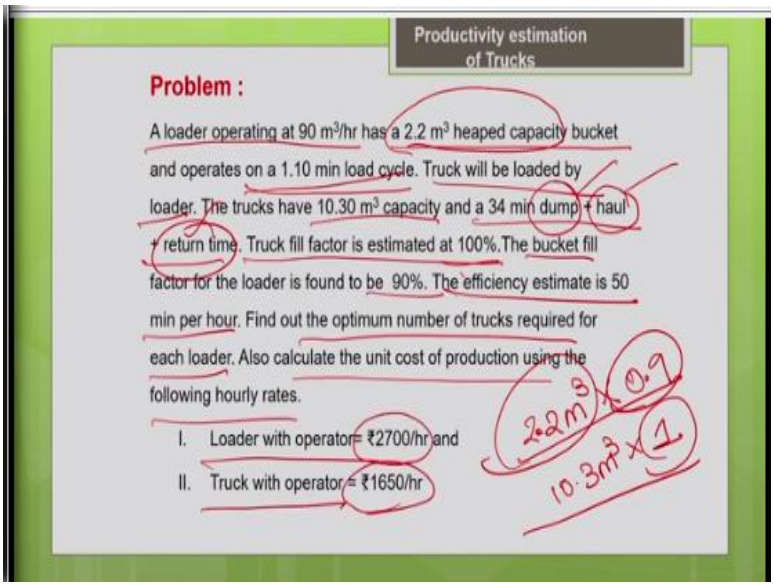

Now let us work on the problem on balancing the interdependent machines**.** So, here a loader is operating at 90-meter cube per hour and it has a 2.2 heap capacity bucket, and operates on 1.1-minute load cycle. The cycle time of the bucket is given as 1.1 minute, a cycle time per cycle it is 1.1 minute for the bucket of the loader. Truck will be loaded by the loader and the truck's capacity is 10.3-meter cube capacity and 34-minute dump + haul + return time.

Other than loading what is the time needed for dumping, hauling and returning is given directly to you**.** If it is not given then you have to go for the performance chart to find out the haul time and the return time and you can go by the manufacturer's data for the dump time. Truck fill factor is estimated at 100%, so based upon the filling ability of the material it is given as 100% for truck but for the bucket it is given as 90% based upon the filling ability of the material.

So, whatever the rated heaped capacity given by the manufacturer I have to adjust with the fill factor. Say for the loader bucket it is 2.2-meter cube, this is the rated heaped capacity given by the manufacturer adjacent with the bucket fill factor 90% 0.9. Similarly, for the truck it is 10.3-meter cube, here the filling factor is 1 that is it. So, you have to get the realistic estimate of the load

volume by adjusting the rated heaped volume with the bucket fill factor or the truck fill factors accordingly.

The efficiency estimate is 50 minute per hour the job efficiency is given that means the machine is working for 50 minutes in a hour. Find out the optimum number of trucks required for each loader. So, we are going to find the balance number at which your productivity is going to be optimum. Also calculate the unit cost of production using the following hourly rates the hourly rate or the hourly cost associated with the loader including the operator cost is given as rupees 2700 per hour and for the truck it is given as rupees 1650 per hour.

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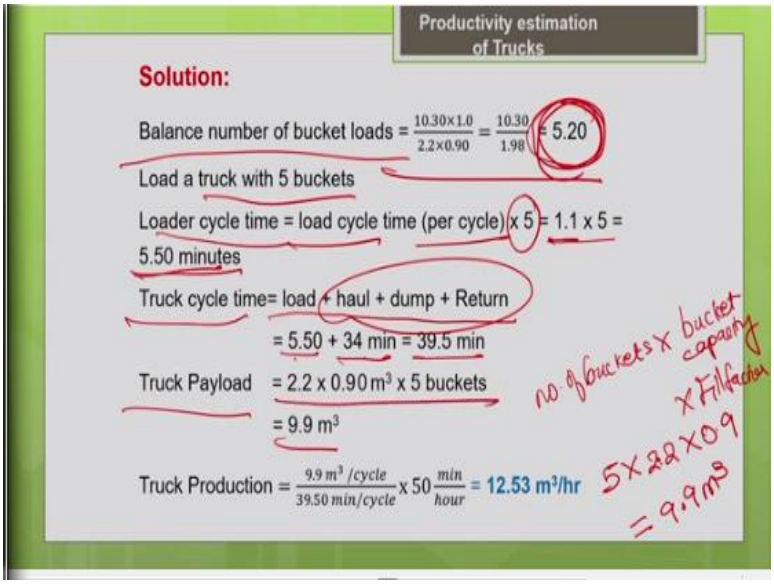

Now let us work out the solution, the first step will be to find the balance number of the bucket loads needed to fill the truck. How will you find the balance number of bucket loads needed to fill the truck? It depends upon your truck capacity and by your bucket capacity, so what is your truck capacity? It was given as 10.3-meter cube, you adjust it with the fill factor, truck fill factor is given as 1.

$$\textbf{Adjusted truck capacity} = 10.3 \times 1 = 10.3 m^3$$

Similarly, the bucket capacity is given to you as 2.2-meter cube, you adjust it with the fill factor it is nothing but 0.9,

$$\textbf{Balance number of bucket loads} = \frac{10.3 \times 1}{2.2 \times 0.90} = 5.2$$

So, you will get the answer is 5.2**.** You can see here 5.2 is the balanced number of bucket loads. So, we did not get a whole number, now I have to round it. In this case it is lesser than 5.5, so I can round it to 5 bracket loads, but if it is going to be 5.5 or greater than that it is preferable to work out the economics of both the cases as I mentioned earlier.

If with 5 buckets what will be the 5-bucket load, what will be the unit production cost, with 6 bucket loads what will be the unit production cost? You are supposed to work it out to make a right decision**.** But in this case, it is lesser, so I am rounding it to lower number 5 buckets. So, obviously I am going to load the truck not to it is fullest capacity, the truck load is short load here short load**.**

Now how to find the loader cycle time to fill the truck? It depends upon the number of the bucket loads that is 5 multiplied by the cycle time of the bucket per cycle

Loader cycle time = 5 × 1.1 = 5.5 minutes

Now what will be the truck cycle time, truck cycle time is nothing but loading + hauling + dumping + returning.

So, this value is completely given to you in the problem is 34 minutes haul + dump + return, loading time you have just now estimated 5.5 minutes. So, 5.5 + 34 gives you 39.5 minute as a truck cycle time, now I need to find the truck payload. So, here you know that I am not going to load the truck to it is full capacity because I am rounding the bucket loads to lesser than the balance number.

Truck cycle time = 5.50+34 = 39.5 minutes

So, the truck payload will be equal to your number of buckets into bucket capacity rated bucket capacity multiplied by the fill factor. So, number of buckets balance number we have taken is 5, bucket capacity is given to you as 2.2-meter cube, fill factor is 0.9. If you multiply you will get the answer is 9.9-meter cube that is what is given here 9.9-meter cube. Now you find the truck production you can easily find the truck protection.

Truck payload = 2.2 × 0.9m^3 × 5 buckets = 9.9m^3

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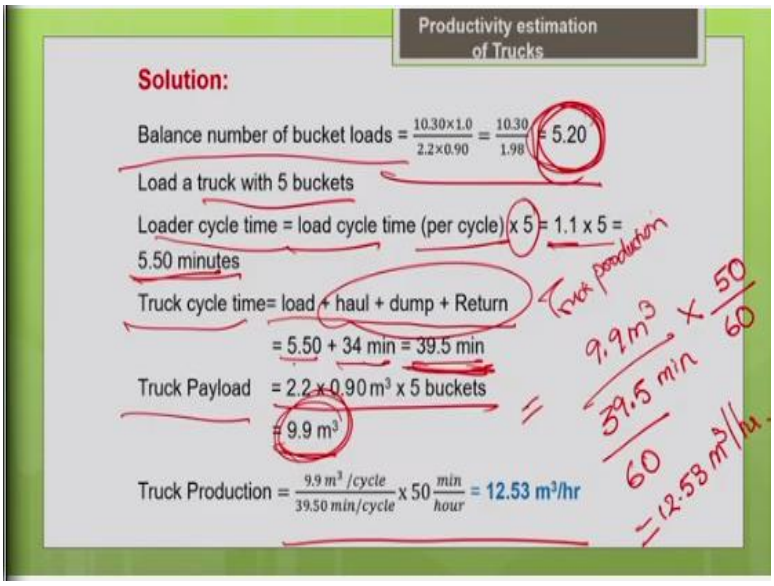

So, what is the volume of truck you are going to load in this case 9.9 meter cube, you are also supposed to check whether the truck payload is within the gravimetric capacity. If say gravimetric capacity is given by the manufacturer you have to check whether the weight of the load of material in the truck is within the gravimetric capacity. For that you need the input data of the density of the material also.

Now let us calculate the truck production, truck production is nothing but your truck capacity, I mean the truck payload**.** Here it is not full load, it is short load 9.9 meter cube we have derived here divide by the truck cycle time, cycle time is 39.5 minute. Since it is in minute I need to convert it into hours, so let me divide it by 60. And another important thing you should never forget is job efficiency, the machine is going to work for 50 minutes an hour 50 by 60. So, this will give me the answer is 12.53-meter cube per hour, so this is how you have to estimate the truck productivity.

$$\textbf{Truck production} = \frac{\textbf{9.9m3/cycle}}{\textbf{39.5m3/cycle}} \times \textbf{50}\boldsymbol{min/hr} = \textbf{12.53 m}^{\textbf{3}}\textbf{/hr}$$

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