Construction Methods and Equipment Management
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Lecture-12
Earth Moving Equipment-Scrapers (Part-2)

Hello everyone, I welcome you all to the lecture 12 of this course. In this lecture, we are going to continue our discussion on the scrapers.

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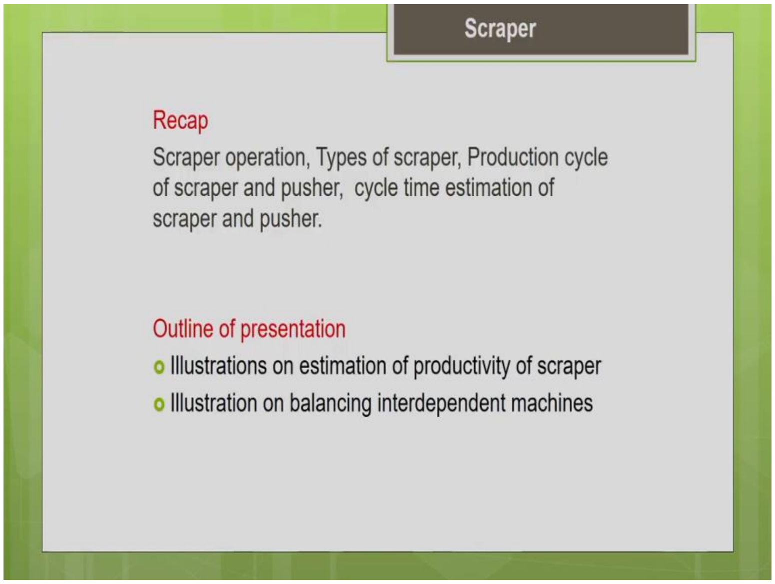

So, in the previous lecture, we have discussed about the operation of the scraper, types of the scraper and we also discussed about what are all components of the production cycle of the scraper and the pusher and how to estimate the cycle time of the scraper and the pusher. So, in this lecture, we are going to discuss or we are going workout some problems on the estimation of the productivity of the scraper. And we will also work out some problems on balancing the number of scrapers and the pushers which are the interdependent machine.

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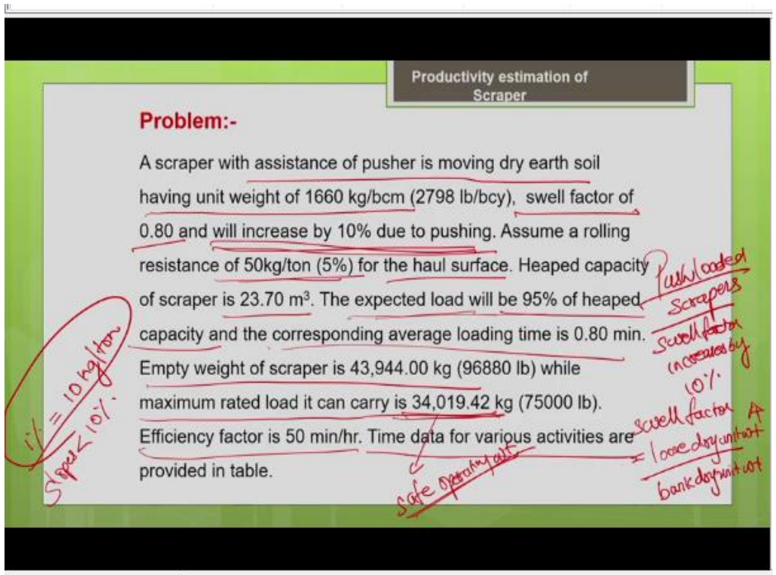

So, now, let us work on the first problem on productivity estimation of the scraper. So, a scraper with the assistance of the pusher is moving the dry earth soil having unit weight of 1660 kg per bank meter cube. So, you can see that this is a conventional pusher loaded scraper, here we are moving the material which is dry earth soil, its unit weight is given 1660 kg per bank meter cube.

So, the volume is given in volumetric measures is a bank state. So, that you have to clearly note it and the swell factor has given as 0.80. So, with the help of the swell factor you can do the conversion like from loose volume, you can convert it into bank volume or vice versa and you should know that this swell factor will increase by 10 % due to pushing. Why is it particularly for the push loaded scrapers?

Your swell factor increases by 10 % due to pushing. So, basically you know that when the pusher is pushing the scraper. It offers more additional pressure to push more material into the bowl. So, because of the additional pressure what is happening more and more material gets compacted inside the scraper bowl. So, due to the compaction of the material inside the bowl, you can see that the unit weight of the material inside the bowl will increase.

So, that results in increase of your swell factor. So, hope you remember what is swell factor? We have defined what is swell factor in early lecture, it is a ratio of loose dry unit weight of the material by bank dry unit weight of the material. So, particularly for the push loaded scrapers your swell factor, the unit weight will increase by 10%, because of the additional pressure which we received from the pusher to the material inside the bowl.

So, the material gets more compacted inside the bowl and because of that the swell factor will increase by 10%. So, this we have to always remember. So, even though the value is not given in the question, you should know that for push loaded scrapers by default swell factor will increase by 10%. Now, assume the rolling resistance of 50 kg per ton for this particular haul route the rolling resistance is 50 kg per ton.

So, if you want to convert it into equivalent gradient, you know that for 1% is a gradient equal to 10 kg per ton. So, this is a conversion factor which we discussed earlier, and this is valid for slopes less than 10%, we can use this. So, 50 kg per ton it is going to be 5%. Heaped capacity the scraper is given as 23.70 meter cube. They expect the load will be 95% of the heaped capacity. So, that means as we discussed earlier, we are not going to load the scraper to its fullest capacity.

If we load it to the fullest capacity, it will result in because of law of diminishing returns which we discussed earlier, it will result in decrease in loading rate after a particular time. So, that is why your loading times will increase a lot. So, the optimum loading time we have to follow for loading which we can derive from the equipment to manufacturer. So, here the expected load capacity is given to be 95% of heaped capacity.

That means we are going to load the scraper only to 95% of the heaped capacity. We are not going to load it to the fullest and the corresponding average loading time is 0.8 minutes. The empty weight of the scraper is given in kg. The maximum rated load it can carry is 34,019.42 kg. That means, this is the safe operating weight of the machine. For every machine, the safe operating weight is given by the manufacturer.

We are not supposed to load the machine beyond the safe operating weight. So, that will affect the structural frame of the machine, it will abuse the machine. If you are going to load it beyond the safe operating weight, it will affect the safety of the machine. So, we have to check whether your load or material within your bowl is going to be within this safe operating weight. That is a very important check we have to do, because the material density will vary from type to type.

So, we have to carefully check for the given material, what is that material weight. So, whether it is within the safe operating weight, we have to check. The efficiency factor has given as 50 minutes per hour the job efficiency. So, your machine is working for 50 minutes in an hour and the time data for various activities are provided to the table which we see in the upcoming slide.

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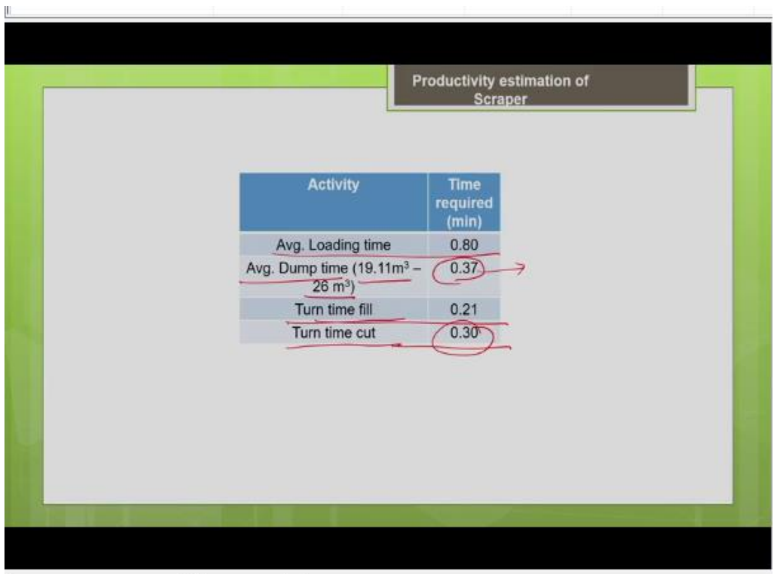

So, we can see it here, the average loading time is given by the manufacturers is 0.80 minute. Hope you remember it is given as 0.80 minute. Average dumping time, you can get it from the manufacturer it is available in the literature also. So, I have taken it from the literature. So, for 19.11 meter cube to 26 meter cube capacity scraper the value of dump time is given as 0.37 minute. As I told you, your dump time is going to depend upon your capacity of your scraper as well as it will depend upon your site constraints the congestion at your site and also depends upon the type of material it is going to handle.

So, you can take it from the manufacturer, the value from any literature. The turn time fill the average value is given as 0.1 minute and turn in time in the cut area is given as 0.30 minute. So, in the cut area it is slightly higher when compared to fill area, we have discussed the reason earlier.

So, these are the fixed time values, which are provided to us in the literature of equipment handbook.

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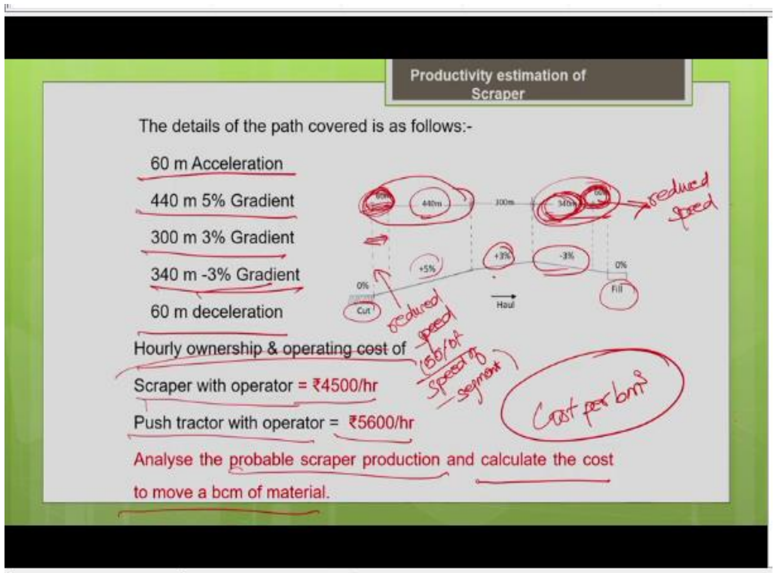

The other input data given is about the path about the haul route, about the haul distance and the resistance encountered in the haul route. So, we can see this is a pictorial representation of the haul route. You have the cutting area, you have the fill area, this is your haul route. So, you can see that for the first initial 500 meters, it is upslope, you have a gradient of + 5%.

Then you have 300 meter, you have a gradient of + 3%m then towards the end you have a distance of 400 meter with a down slope of - 3%. So, since different sections in your haul route have different resistances, particularly the gradients. So, we have to do the estimation section-wise or segment-wise. So, that is the reason we have split the haul route into different sections. So, another important thing you have to note it here is the first 500 meter, I have demarcated 60 meters separately.

This is because when your machine starts, so, when you are accelerating, you need some time for accelerating. So, immediately you cannot attain your desired speed, you need some time for accelerating and to reach the particular desired speed. That 60 meter is for acceleration. So, this initial 60 meter, it is going to be at reduced speed only, the initial phase will be in reduced speed. So, you can take it as approximately 50% of speed of this particular segment.

You can take this speed of 60 meter as 50% of the speed of 440 meter. So, initially you need some time for accelerating. So, that particular distance is 60 meter and these 60 meters this speed will be at reduced speed and we have taken it as 50%. And similarly, towards the end also you can see that out of 400 meter, the last 60 meter you have to slow down your machine. So, the time is needed for slowing down or decelerating.

So, that distance is 60 meter and this distance 60 meter will be also at reduced speed. So, this we can take it as 50% of the speed of the segment 340 meter. So, let me summarize what is given in this question the initial 60 meter distance is for accelerating then 440 meter, you have the 5% gradient, 300 meter you have 3% gradient, 340 meter it is your down slope - 3% gradient.

And the last 60 meter is for reducing your speed deceleration. So, the detail about your haul route is given distance as well as the gradient percentage and you know the rolling resistance. Rolling resistance is already given to you is given here. Assume we are rolling resistance 50 kg per ton 5% is for the haul surface. So, the rolling resistance is uniform throughout only the gradient is varying in the haul route that you have to note it.

Then the hourly ownership and the operating costs of the machine it is given directly to you, you know, we will have to estimate the ownership costs and operating costs. So, we are not going to estimate the cost again it is given as the input data. The scraper with the operator cost is rupees 4500 per hour and for the push tractor with the operator the cost is given us rupees 5600 per hour. Now we are going to analyze and find the probable scraper production and also find the cost to move a bank meter cube of material. So, you have to find the unit cost of production cost per bank meter cube, you need to find the unit cost of earth moving operation.

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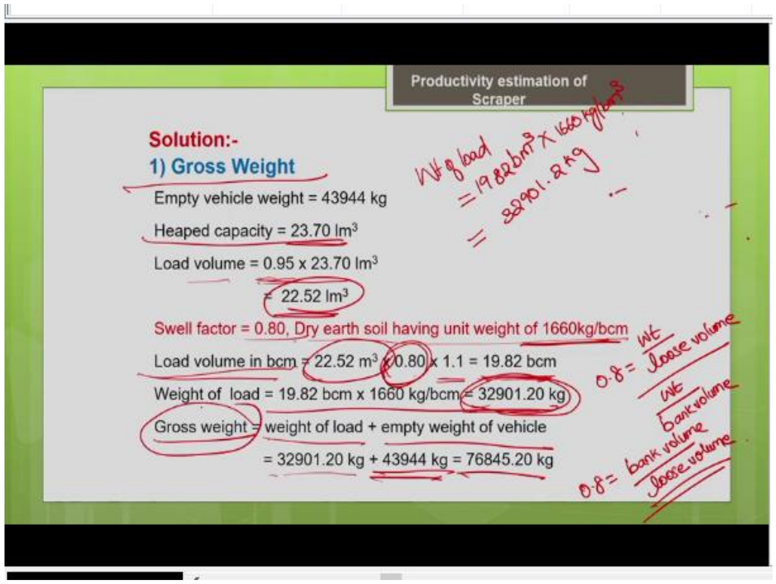

So, let us see how to proceed with this problem. So, the first thing you have to estimate is your gross weight of the machine. So, your gross weight of the machine is nothing but your empty weight plus the weight of the load in the machine, weight of the load in this scraper bowl. So, this is your gross weight the empty weight is given by the manufacturer. Now, I need to find what is the weight of the load in the machine?

But I know what is the volume of your heaped volume of volume of your heaped capacity of your scraper? The Heaped capacity is 23.7 loose meter cube the maximum heaped capacity of the bowl of the scraper when you heap it at a particular angle of repose; it is going to be 23.7 loose meter cube. Now what is the load volume? You need to find it. So, we are not going to load it to the maximum capacity as given by the equipment manufacturer, I will be loading to 95% of the heaped capacity.

So, your load volume is nothing but so how much I am going to load it 95%, 0.95 of your heap capacity. Your heaped capacity is 23.7 loose meter cube. So, that gives me the value as 22.52 loose meter cube, this is your load volume in loose meter cube. So, hope you remember here we have to estimate everything in bank meter cube. Your unit cost of production we have to estimate in cost per bank meter cube.

So, let me convert the loose meter cube into bank meter cube. So, how to convert? For that we need the help of this swell factor. The swell factor is given to you in the question for this particular material for this dry earth. So, the swell factor is given as 0.80. Swell factor is nothing but loose dry unit weight divided by bank dry unit weight. So, now, let me convert it into volume I need it in volume.

Weight divided by loose volume divided by the weight by bank volume. So, 0.8 equal to bank volume by loose volume. So, now, you can find your bank volume. Bank volume equal 0.8 into loose volume. So, load volume in bank cubic meters equal to your loose volume is 22.52 loose meter cube into the swell factor is 0.8. So, now, you have to increase the swell factor by 10% as we discussed earlier, because it is push a loaded scraper because of the additional compaction effect, in the effect on the material inside the bowl your unit weight will increase.

So, you have to increase the swell factor by 10%. So, that is why I have multiplied it by 1.1. So, now you get the answer is 19.82 bank cubic meter. The load volume in bank meter cube is 19.82. So, now let me estimate the weight of the load, weight of the load inside the bowl after I estimate the weight of load I have to check whether it is within the safe operating limits that is also important.

So, the weight of load inside the bowl you know the volume in bank meter cube 19.82 bank meter cube multiplied by the unit weight of the material is given in the question. The dry earth soil have a unit weight of 1660 kg per bank cubic meter is given in the question. You know the material property 1660 kg per bank meter cubed. So, when you multiply both you will get the weight of load as 32,901.2 kg.

So, that is what is derived here, weight of load is 32,901.2 kg. So, let me check what is the safe operating weight of the machine? As given in the question it will be given by the manufacturer. So, the maximum rated load it can carry is 34,019.42. So, this is within the safe operating weight of the machine. Now, let me find the gross weight of the machine. Gross weight is nothing but your weight of the load plus the empty weight of the vehicle.

So, weight of the load you have just determined 32,901.20 plus your empty weight of the vehicle is given in the question for the 43,944, when you add both, you will get the gross weight of the machine as 76,845.2 kg. So, this is how you have to determine the gross weight of the machine.

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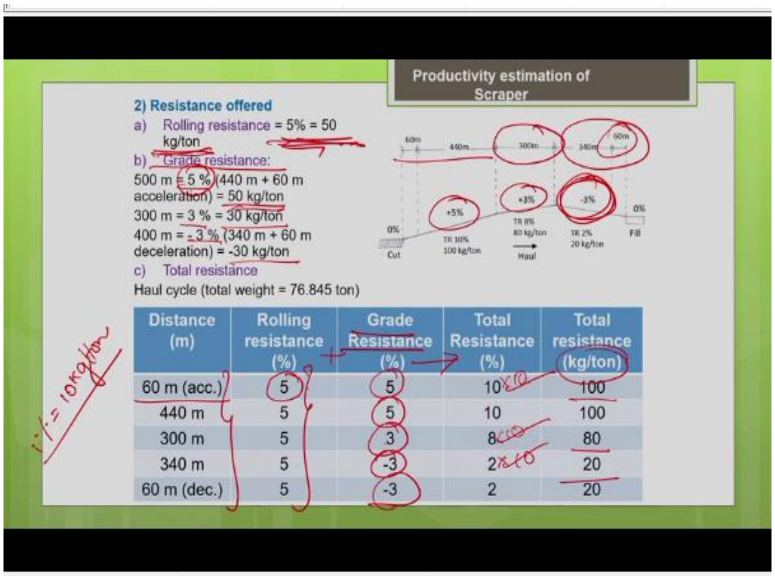

So, now the next step is we have to determine what are all the resistance in the haul route? The rolling resistance is uniform throughout the haul route. Is given in the question is 50 kg per ton or equivalent gradient as 5%. So, whatever way you express, you can take it accordingly. Then the grade resistance, the grade resistance is given for different sections, which we discussed just now. For the first 500 meters it is + 5%.

For the next 300 meter it is +3 % and for the next 400 meter, it is going to be the down slope - 3%. So, as you can also convert it into kg per ton you know the conversion factor 1% equal to 10 kg per ton. This is valid for slope less than 10%. So, you can convert the gradient also into kg per ton, 5% is equal to 50 kg per ton. 3% gradient is equal to 30 kg per ton and - 3% gradient is equal to - 30 kg per ton. Now, we need to find the total resistance.

So, let us prepare it in the form of table so, that it will be very convenient to analyze. So, follow this table formatting. So, we can see the different segments distances. So, for the first 60 meter, the rolling resistance is 5 you can see that for all the segments the rolling resistance is same it is

5% or 50 kg per ton. Next is grade resistance for the 60 meter it is + 5%. The next 440 meter it is + 5%, 300 meter it is + 3%.

Then the 340 meter you can see it is - 3% and the last 60 meters, you can see it is again 3%. You add both rolling resistance percent plus grade resistance, you add both you will get the total resistance in percentage 5 + 5 =10, 5 + 3 = 8, 5 - 3 = 2, so like that you add both. Now, you can also express in kg per ton. Just multiply it by 10, 10 into 10 =100 kg per ton, 8 into 10 = 80, 2 into 10 = 20. So, you can use either one of this, but I have expressed in both.

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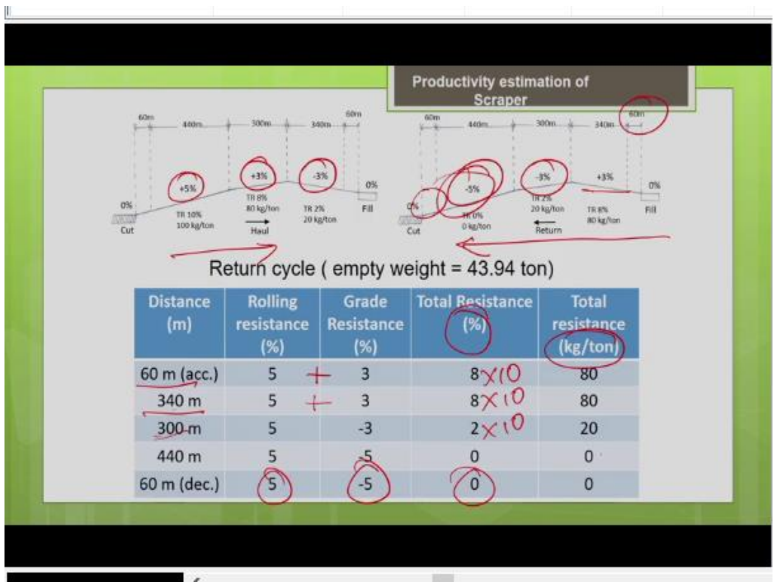

So, that was about the haul cycle. Now, it is about the return cycle. The return cycle you have to be very careful in analyzing the haul route. You know that now the machine is moving from this end to this end. So, whatever gradient we have discussed here in the haul travel, say here if it is + 5%, in your return travel it is going to be - 5%. Similarly, here it is + 3%. In return travel it is going to be - 3%. Here this is - 3% in return it is going to be + 3%. So, whatever it was upslope in your haul travel in a return travel it is going to be downslope. So, accordingly, you have to choose values and then estimate it correctly.

So, now, let us see for the first 60 meter here the first 60 meter. You can see the gradient is + 3%. As I mentioned earlier the rolling resistance is going to be same for the entire haul route. For the next 340 m obviously, it is same + 3%. Now, for the next 300 meter, you can see it is now down the slope. So, it is - 3%. For the 440 meter, it is again down the slope. So, it is - 5%. The last 60 meter distance where you reduce the speed. It is again - 5%.

Now, add both rolling and grade resistance. So, that you can get your total resistance percentage 5 + 3 = 8, 5 + 3 = 8, 5 - 3 = 2, 5 - 5 = 0, 5 - 5 = 0. You can also convert the resistance percentage into kg per ton multiplied by 10, 80 kg, 80 kg, 20 kg, 0 and 0. So, now, we have determined the total resistance in percentage as well as in kg per ton for the entire haul route as well as for the return route. So, in order to determine the speed of the machine, I need the help of the performance chart. So, now with the help of the performance chart, if you know the total resistance and if you know the gross weight of your machine you can calculate the speed of machine as we discussed earlier.

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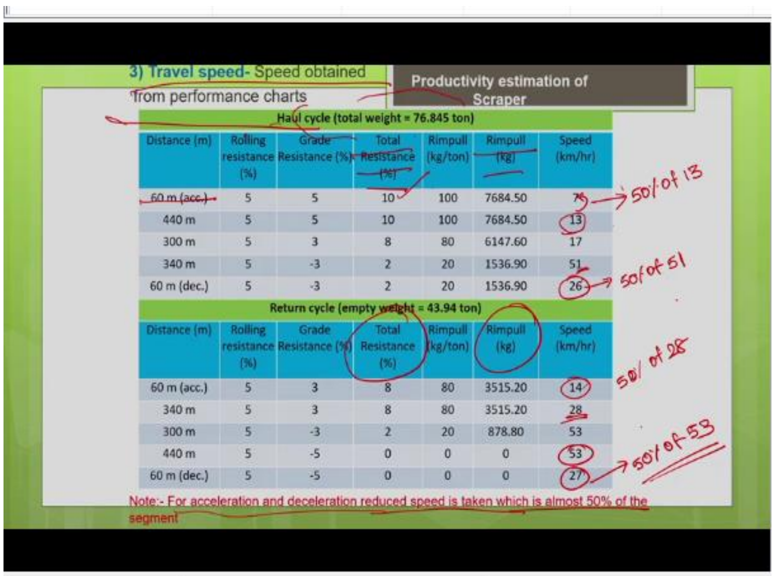

Now I need to determine the travel speed from the performance chart. The total weight of the machine is express in tons 1000 kg equal to 1 ton. Accordingly, we have to convert it into tons. So, during the haul cycle, it is a loaded condition 76.845 ton. During return cycle it is empty. So, the empty weight of the vehicle is 43.94 tons. So, you have already calculated your total resistance already in both percentage as well as kg per ton. We are already determined in the earlier slide.

Now, using the performance chart, hope you remember the performance chart either I can use the total resistance percentage or I can use the rimpull value. So, hope you remember in the left hand side, you have the performance chart, in the left hand side you have the rimpull and in the right hand side you have the total resistance in the percentage, in the x axis you have the speed. So, based upon your different gear curves, we have discussed this already we have to based upon your total resistance you have to find the speed of the machine from the performance chart.

So, this rimpull in kg see already we have determined earlier for kg per ton. So, according to the weight of machine, so here the gross weight of machine is 76.845 ton. So, multiply rimpull and kg per ton into the gross weight of the machine. You will get the total rimpull in kg. So, 100 into 76.845 gives you 7,684.5. Similarly, 80 into 76.845 gives you 6,147.6 kg. So, this 80 kg per ton is converted into 6,147.6.

Similarly, 20 kg per ton multiply with a gross weight of machine 76.845 it gives you 1,536.9 kg total rimpull in kg. So, you can do the conversion. So, use this total rimpull or total resistance either of these you can use and find the corresponding speed in the performance chart. So, I have assumed some approximate values. Actually, you are supposed to choose it look for the correct scraper model number.

Take the equipment handbook, in the equipment handbook, look for the particular model number you will have the performance chart for the model number, then from the performance chart, you know the total rimpull or corresponding speed you can find it or with the help of total resistance percentage corresponding speed you can find it. Similarly, for your return cycle, the rimpull weight is given kg per ton already we have determined, based upon the empty weight of machine 43.94 you find the total rimpull.

So, it is nothing but 43.94 multiplied by 80, 43.94 multiplied by 80 gives you 3515.2 kg, similarly, say here 20 kg per ton. So, 20 multiplied by the empty weight of the machine is 43.94 tons. So, that gives you the value is 878.8 kg, this is a total rimpull. So, you can use your either the total rimpull value or the total resistance percentage and find the speed. So, one thing you can note here is your return speed is higher when compared to the haul speed.

Because this is in loaded condition, return speed is in empty condition. So, the speed is obviously higher. So, another important thing you have to note it here is say the 60-meter initial segment for acceleration, I have taken it approximately as 50% of 13, it gives me the speed for the initial portion of the segment where you need some time for accelerating that portion will be at the reduced speed only.

Similarly, towards again the last 60 meters when you try to reduce the speed, so, that will be also you have to take it as 50% of the previous one, that is 51, 50 % is a 51 approximately 26. Similarly, for your return travel this is the initial segment take it as 50%, your 14 is nothing but 50% of your 28. Similarly, the last segment 27 you take it as 50% of your previous one 53. So, that will give you 27 approximately. So, for acceleration and deceleration reduce speed is taken which is almost 50% of the segment, we discuss the reason already earlier.

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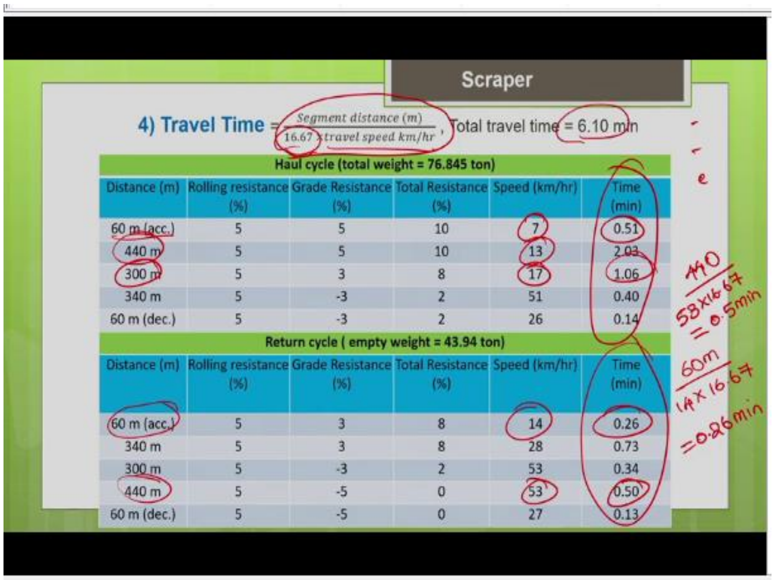

Haul cycle (total weight = 76.845 ton)					
Distance (m)	Rolling resistance (%)	Grade Resistance (%)	Total Resistance (%)	Speed (km/hr)	Time (min)
60 m (acc.)	5	5	10	7	0.51
440 m	5	5	10	13	2.03
300 m	5	3	8	17	1.06
340 m	5	-3	2	51	0.40
60 m (dec.)	5	-3	2	26	0.14
Return cycle (empty weight = 43.94 ton)					
Distance (m)	Rolling resistance (%)	Grade Resistance (%)	Total Resistance (%)	Speed (km/hr)	Time (min)
60 m (acc.)	5	3	8	14	0.26
340 m	5	3	8	28	0.73
300 m	5	-3	2	53	0.34
440 m	5	-5	0	53	0.50
60 m (dec.)	5	-5	0	27	0.13

So, now, you need to calculate the travel time. So, we have calculated the speed. You know the speed for different segments. You know the haul distance for different segments. Now, you can calculate the travel time. So, time is nothing but your distance by speed, for every segment you are going to calculate it. Say for the first 60 meter, the speed is given in kilometers per hour 7 kilometer per hour. Haul distances is in meter.

So, let me convert it to a kilometer per hour into meter per minute, 1 kilometer per hour equal to 16.67 meter per minute the conversion factor. So, multiplied by 16.67. So, you will get the answer is 0.51 minute. Your travel time is segment distance divided by travel speed kilometer per hour into 16.67, that is your conversion factor. Similarly, do it for all the segments one by one.

Say for the next segment for 440 meters the distances is 440 divided by distance is 440 speed is 13, the conversion factor is 16.67. This gives me the answer is 2.03 minute. The next segment is 300 meter. The distance is 300, speed is 17, the conversion factor is 16.67 that gives you the answer is 1.06 minute. Similarly, you can do it for everything, the same way for the return time. So, return time you can see for the first segment it is 60 meter divided by the speed is 14 kilometer per hour into the conversion factor is 16.67 that gives you the time is 0.26 minutes.

Similarly, say 440 meters 440 divided by the speed is 53 the conversion factor is 16.67, you get the time as 0.5 minutes. So, add all the time for the haul route. Haul time as well as the return time. If you add everything you will get the total travel time is 6.1 minute.

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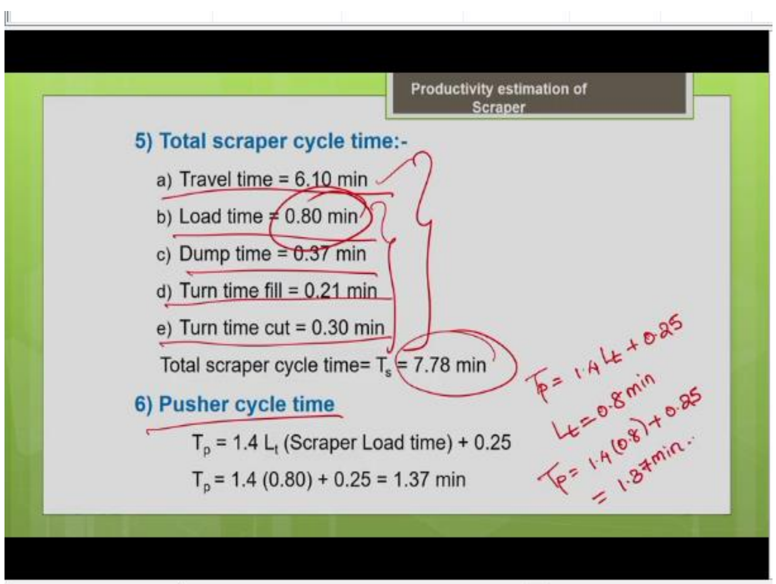

So, this is how you have to determine the total travel time. Let me know the summary is whatever we have discussed so far. The travel time we have determined is 6.1 minute, hope you remember the travel time is 6.1 minute. Loading time is 0.8 minute. Dump time 0.37. Turn time 0.21. Turning time in cut area 0.3 minute. So, these are only a fixed time. This is your variable time and add everything you will get the total scraper cycle time is 7.78 minutes.

You have to add everything. Now find the pusher cycle time. So, pusher cycle time I am going to follow backtrack loading method. So, let me use a caterpillar formula, that is nothing but

$$T_P = 1.4\ L_t + 0.25,$$

your loading time you know already it is 0.8 minute. So, your pusher cycle time is 1.4 into 0.8 + 0.25. So, that gives you the answer is 1.37 minutes. So, we have estimated the scraper cycle time and the pusher cycle time.

The next thing is we have to balance the number of scrapers and the pushers. Like I say as I mentioned earlier, we need to balance the interdependent machines so that one need not wait for the other. So, by this we can reduce the waiting time of the machine. So, that way you can reduce the cycle time of the production and you can increase the productivity and reduce the production cost. So that is why we have to go for balance number of scrapers and pusher so that we can minimize the waiting time of the machines.

So as we discussed earlier, you know that the pusher cycle time it is going to be relatively smaller than the scraper cycle time. This is because your pusher will be helping the scraper only during the loading phase. Once a scraper bowl is completely filled so now the scraper will get detached from the pusher and it can haul the material on its own. So, scraper needs the assistance of the pusher only during its loading phase that is why one pusher can serve even up to 4 to 5 scraper.

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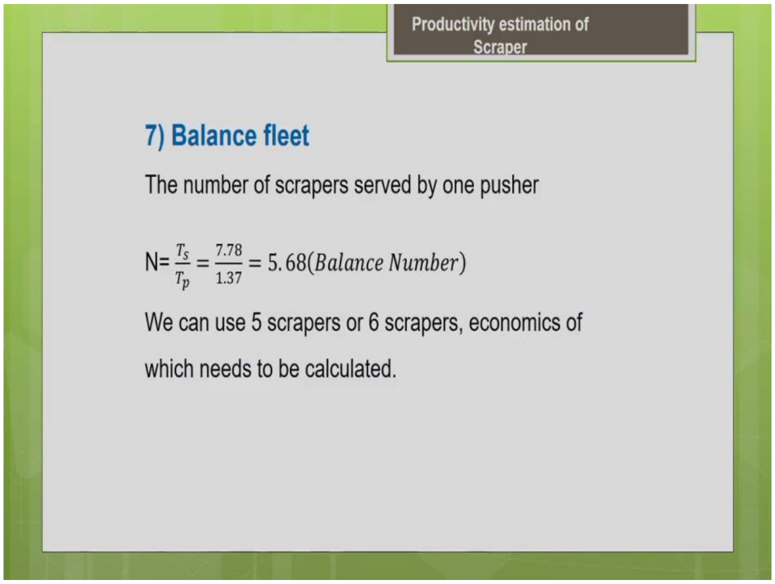

Now let us see the balanced number of scrapers which are served by one pusher. So, that is equal to n is nothing but number of scrapers served by one pusher. It is equal to cycle time of the scraper by cycle time of the pusher. So, here we have estimated the cycle time of the scraper as 7.78 minute. And the pusher cycle time is 1.37 minutes. So, it is 7.78 divided by 1.37 gives you the value as 5.68.

$$\text{N} = \frac{T_s}{T_p} = \frac{7.78}{1.37} = 5.68(Balance\ Number)$$

So, now the balanced number is 5.68. This balanced number indicates the level at which the production level of both the machine are same scraper and the pusher. So, it means both are working at a maximum production level, but it is not possible for us to go by 5.68 per pusher. So, we have to round it. Since we get the decimal number, we have to either round it to the lower number or rounded to the higher number. Either I can go for 5 or I can go for 6.

So, we have to work out the economics of both the cases. If I go for 5 scrapers what will be the associated productivity and production cost? If I go for 6 scrapers what will be the production and unit production cost? We have to work out the economics and take a call whether to go for 5 scrapers or 6 scrapers accordingly.

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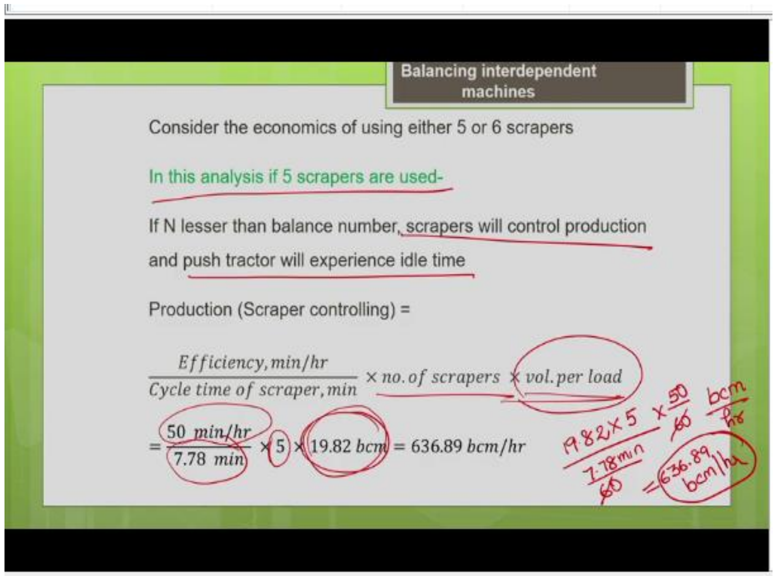

Now let us consider the economics of going for 5 scrapers. So, 5 in the sense you are going to use lesser than what is needed, you are assuming 5 that means you are going to use the number of scrapers lesser than what is needed. So, when the number of scrapers are lesser than the balanced number so obviously scrapers are more critical, but a pusher will have the ideal time. Your pusher will wait for the scraper.

So, unless a scraper is available you cannot complete the job. So, here the scraper will be controlling the production as a scraper is a lesser in number, but the pusher will have the ideal time. So, now, let us see the productivity this case of n equal to 5 scrapers. How to estimate the production of this scraper? The volume of your bowl volume per load, you know the value of 19.82 bank cubic meter.

$$Production\ (Scraper\ controlling) = \frac{Efficiency, \frac{min}{hr}}{Cycle\ time\ of\ scraper,\ min} \times no.\ of\ scrapers \times vol.\ per\ load$$

$$= \frac{50\ \ min/hr}{7.78\ \ min} \times 5\ \times 19.82\ bcm = 636.89\ bcm/hr$$

We need the unit production cost in terms of the cost per bank meter cube. That is why we have to estimate the production also in the bank cubic meter. So, it is already estimated earlier the volume per load that is a volume of the bowl is 19.82 bank cubic meter. The payload in the bowl. Now the number of scrapers is 5. In this case we have taken it as 5, the cycle time of the scraper is 7.78 minutes and the job efficiency machine is going to go 50 minute in an hour.

Now you just multiply it and you will find it. So, basically the volume per load is 19.82 multiplied by the number of scrapers is 5. So, divided by the scraper cycle time is 7.78 minute. So, I need the production bank cubic meter per hour. So, let me convert this a cycle time in hour divided by 60. Then the job efficiency machine is going to work for 50 minutes an hour. So, 50 divided by 60.

So, these 2 things gets cancelled, so, the resultant value will be 636.89 bank cubic meter per hour. So, this is your production if you go for 5 number of scrapers per pusher. Similarly, let us estimate for 6 number of scrapers.

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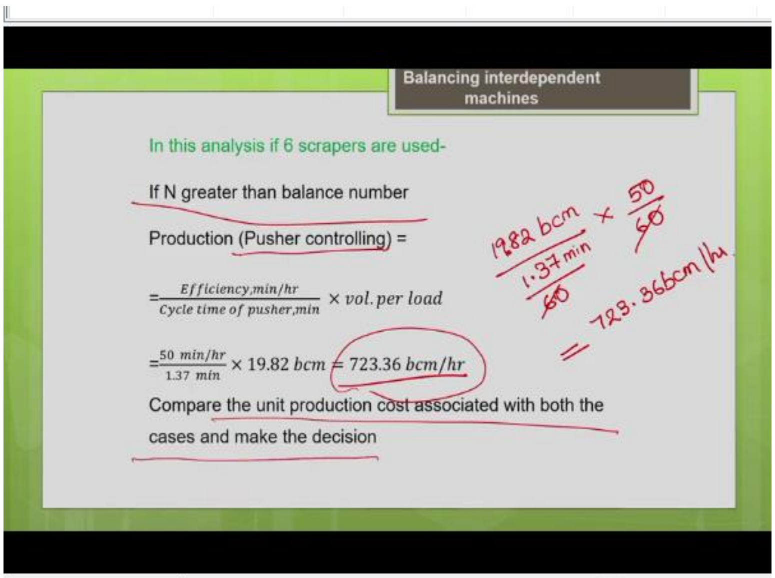

If n is greater than the balance number that means you are going to use more number of scrapers, then what is indicated by the balance number. In this case, scrapers will have the ideal time. Scrapers are not critical. So, the scraper will be waiting for the pusher. Pusher is critical here. So, unless the pusher is available, I cannot complete the job. So, in this case pusher will be controlling the production. Pusher cycle time is critical. So, unless a pusher is available, I cannot complete my job.

I have scrapers more than what is needed. So, in this case how to estimate the production?

$$Production\ (Pusher\ controlling) = \frac{Efficiency,\ min/hr}{Cycle\ time\ of\ pusher,\ min} \times vol.\ per\ load$$

$$= \frac{50\ \ min/hr}{1.37\ \ min} \times 19.82\ bcm = 723.36\ bcm/hr$$

Production is pusher controlling, so the volume per load is 19.82 bank cubic meter divided by the cycle time of the pusher. Cycle time of pusher is 1.37 minute convert it into hours divided by 60. Now multiply with a job efficiency machine is working for 50 minutes an hour, it gets cancel. So, the production will be 723.36 bank cubic meter per hour.

So, that is what is given here. So, basically when you use lesser number of the scrapers, scraper will be controlling the production, lesser than the balance number. When you are using more number of scrapers in that case pusher will be critical, pusher cycle time will control the production. So, that is only to estimate the production of the teamwork. So, now we have estimated the productivity.

Based on productivity if I select obviously I have to go for 6 number of scrapers per pusher, because 5 scrapers is giving you 636.89, 6 scrapers is giving you 723.36 bank cubic meters per hour. So, obviously 6 scrapers per pusher is giving you higher productivity. So, if you are more concerned about the productivity, if you have very tight deadline, you have to finish the project faster.

In that case people prefer to go for the combination which gives you higher productivity, but very often we see that people are more concerned about the cost only. So, people prefer for the combination which gives them minimum production cost. So, that is why now let us compare unit production costs associated with the both the cases and then let us make the decision.

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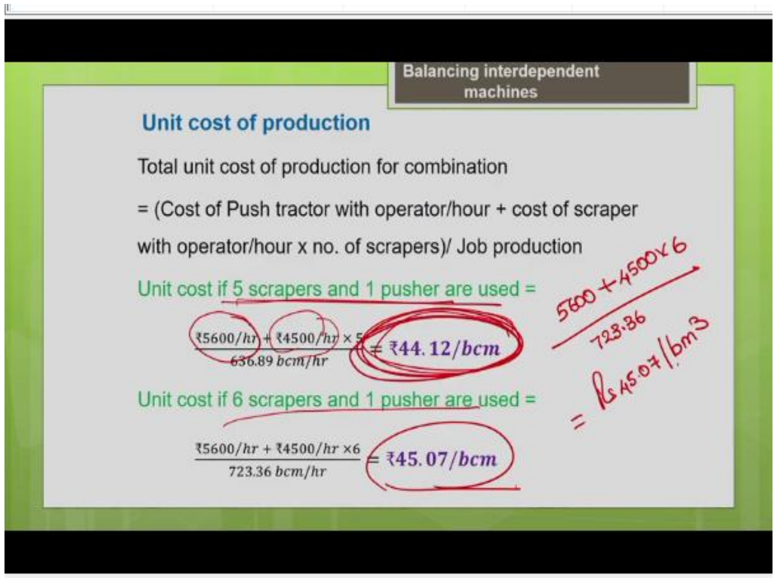

Let us now estimate the cost. How to calculate the unit production cost?

$$Total\ unit\ cost\ of\ production\ for\ combination$$
$$= \left[\frac{\frac{Cost\ of\ Push\ tractor\ with\ operator}{hour} + \frac{Cost\ of\ scraper\ with\ operator}{hour} \times no.of\ scrapers)}{Job\ production}\right]$$

So, cost per bank meter cube. So, it is nothing but you hourly cost by hourly productivity. Now, how to estimate the hourly cost? Already it is given to us input data in the question, but you know how to estimate the ownership costs and the operating costs of the machine which we have discussed in the earlier lectures.

So, in this problem, it is given to you that the hourly cost of the pusher is rupees 5600 per hour, hourly cost of the scraper is 4500 per hour. So, including the operator cost it is given to you. So, now it is estimated cost per bank per cubic meter for the case of 5 scrapers and 1 pusher. So, the pusher cost is given as 5600 per hour, scraper cost is 4500 for 1 scraper. So, we are going to use 5 scrapers and multiply it by 5 divided by hourly productivity for this combination is 636.89.

$$Unit\ cost\ if\ 5\ scrapers\ and\ 1\ pusher\ are\ used\ = \frac{₹5600/hr\ +\ ₹4500/hr\ \times\ 5}{\frac{636.89\ bcm}{hr}}$$

$$= \mathbf{₹44.12/bcm}$$

That is 5 scrapers and 1 pusher the productivity values 636.89. Now the answer will be rupees 44.12 per bank meter cube or bank cubic meter. Now let us estimate the unit production costs associated with 6 scrapers and 1 pusher.

$$Unit\ cost\ if\ 6\ scrapers\ and\ 1\ pusher\ are\ used\ = \frac{₹5600/hr\ +\ ₹4500/hr\ \times 6}{\frac{723.36\ bcm}{hr}}$$

$$= ₹\mathbf{45.07/bcm}$$

So, the cost of 1 pusher is 5600, the cost of 6 scrapers 4500 multiply by 6 divided by your productivity of combination is 723.36 bank cubic meter per hour. So, this gives you the cost is rupees 45.07 per bank meter cube.

So, if you are concerned more about your production cost only. In that case most of the cases people are concerned only about minimizing the production cost. So, in that case we have to go for the combination which gives you the minimum unit production cost. So, the combination of 5 scrapers and 1 pusher gives you the minimum unit production costs. So, let us go by this 44.12.

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The solution is we are going for 5 scrapers and 1 pusher. The associated production value is 636.89 bank cubic meter per hour and the unit production cost associated is rupees 44.12 per bank cubic meter. So, this is how we have to estimate the productivity and the unit production costs for the pusher loaded scrapers. So, we need to balance the number and for the balance combination for optimum combination we have to estimate the cost.

Now, let us work out the next problem on scraper. So, in this problem, we are going to check whether the rimpull generated is sufficient for doing the desired job, whether the rimpull is sufficient I hope you remember what is rimpull, the usable force is a tractive force at the point of contact between the wheel and the ground.

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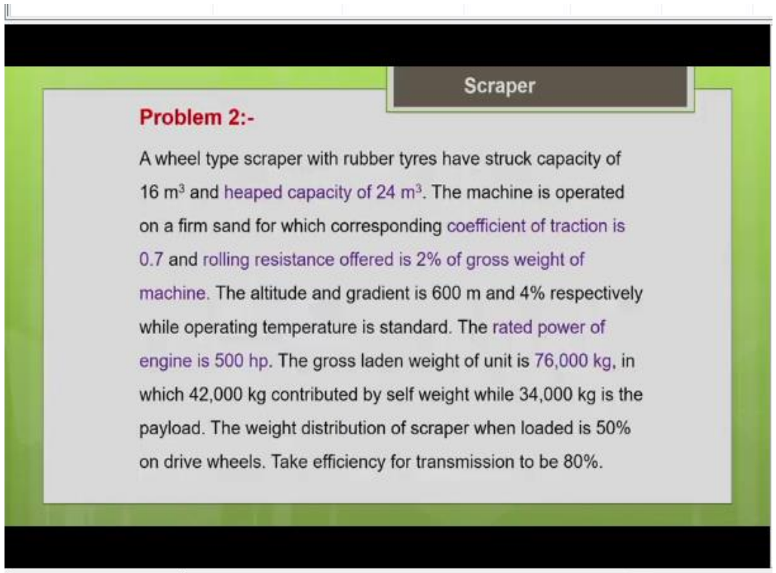

Whether the force generated is sufficient to do the required job or not, we need to check in this problem. So, here a wheel type scraper is given with rubber tyres having struck capacity of 16 meter cube and heaped capacity of 24 meter cube. Hope you know the difference between struck capacity and heaped capacity. So, we are interested in heaped capacity only. The machine is operated on a firm sand for which the corresponding coefficient of traction is 0.7.

And the rolling resistance offered is 2%. It is express as percentage of gross weight of the machine, the gross weight is nothing but your self-weight of the machine plus the weight of the load in the machine the payload in the machine. The altitude is 600 meter and the gradient is 4% and the operating temperature is standard temperature. So, that means you need not do any correction for temperature, but the machine is working at an altitude of 600 meter.

So, this associates some correction with respect to altitude. And the gradient is 4%, the rated power of the engine is 500 horse power and the gross weight is 76,000 kg which includes a self weight of 42,000 kg and payload weight of 34,000 kg, the weight distribution of the scraper when loaded is 50% of the drive wheels. So, only 50% of it is on the drive wheels. And take the efficiency for transmission to be 80% that means the machine is the efficiency in transferring the engine power to the usable rimpull is 80%. So, the efficiency in transferring the machine power the engine power into the usable power is 80%.

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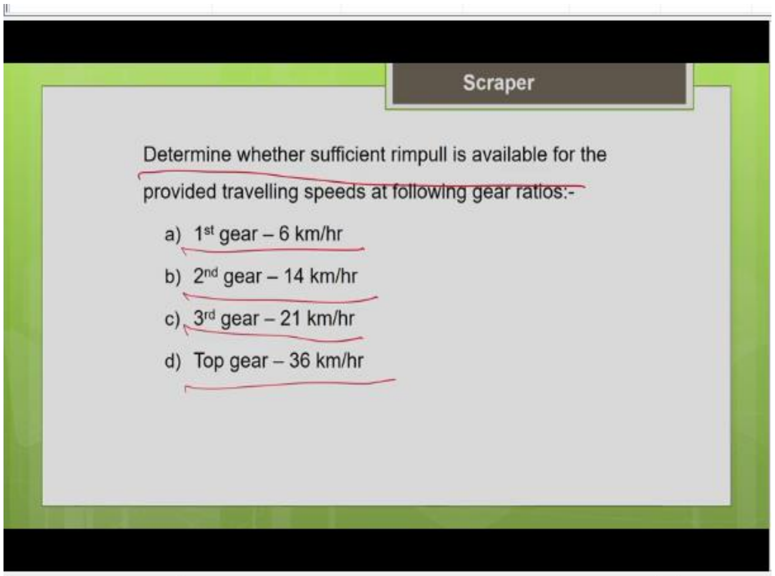

Determined whether sufficient rimpull is available for different speeds different gears you can see first gear 6 kilometer per hour, second gear 14 kilometer per hour, third gear 21 kilometer per hour and the top gear that is 36 kilometer per hour. For these different gears that is the rimpull is sufficient to do necessary job that is what we are going to find it.

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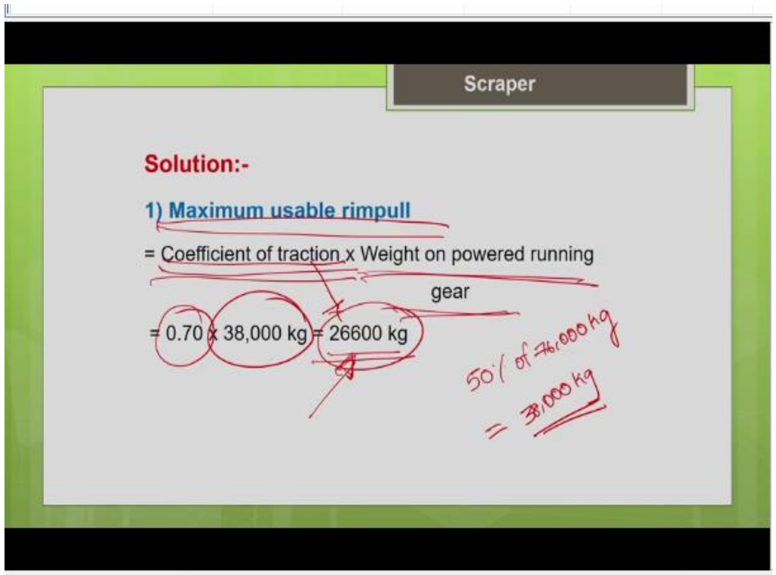

So, first what we need to determine is the maximum usable rimpull. As we discussed earlier the rimpull the maximum usable rimpull for any machine. So, depends upon the coefficient of traction between the wheel and the haul route, wheel and surface. So, irrespective of whatever may be the horsepower capacity of the machine. So, the usable rim power depends upon the coefficient of traction.

$$Maximum\ usable\ rimpul = Coefficient\ of\ traction \times Weight\ on\ powered\ running\ gear$$

So, your horsepower capacity of the machine may be very high, but if the coefficient of traction is insufficient. In that case most of your engine power will not be converted into usable power. So, how much amount of engine power will be converted into usable power depends upon the coefficient of traction? So, between your wheel and the surface, that is why sufficient traction is needed for the conversion of most of your engine power into usable power.

If there is no sufficient traction, there will be slippage of wheels. So, in that case conversion will be poor. So, that thing you should always keep in mind. So, the usable rim power depends upon the coefficient of traction and the weight on the power running gear. That means in your machine all the excess may not be power, only some access may be power and those corresponding wheels only will be driving wheels. So, we are concerned only on the weight of the driving wheels for the usable power generation.

So, that is why we take the weight of the powered running gear. So, the coefficient of traction in this problem is 0.7 and the weight on the powered running gear is given as 50%. It is given in the question as the weight distribution when loaded is 50% on the drive wheels and the gross weight you know it is 76,000 kg. So, 50% of 76,000 kg. So, that gives me the weight on the driving wheels as 38,000 kg. That is what is taken here.

So, 0.7 into 38,000 kg gives you the maximum usable rimpull 26,600 kg. Even if the rimpull based upon the horsepower of the machine is going to be greater than this. Say for example, if the horsepower generated rimpull is going to be greater than this. In that case, you have to go by this value only, only this will be the maximum limit. So, the coefficient of traction will decide the maximum usable rimpull.

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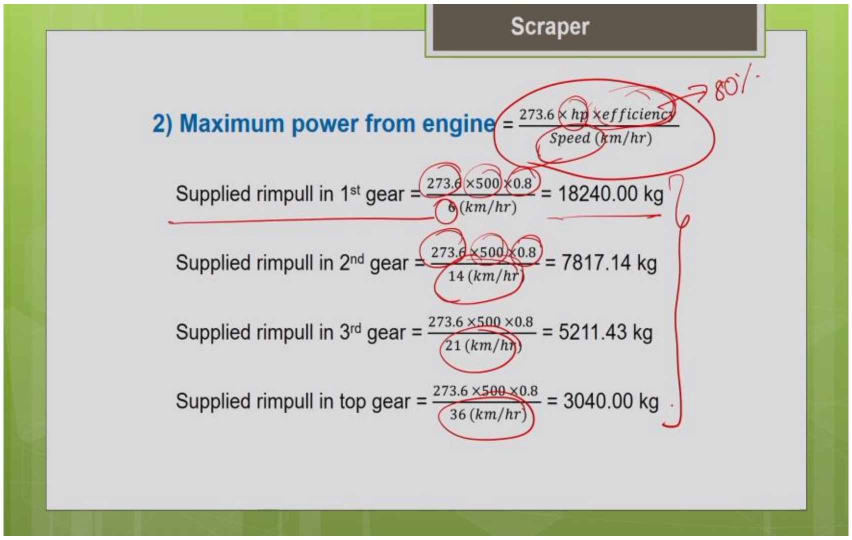

So, now let us estimate the maximum power from the engine based upon the horsepower of the machine, hope you remember this formula which we are discuss in the earlier lecture, it is nothing but rimpull equal to 273.6 into horsepower into the efficiency in transferring the horsepower into the usable power, here it has given as 80% in this problem and the speed which depends upon the gear. So, the supplied rimpull in the first gear equal to 273.6 multiplied by horsepower is 500, efficiency is 80% and the speed in the first gear is given as 6 kilometer per hour.

Hope you remember, the speeds are given here as input data. So, the supplied rimpull is 18,240.00 kg. Now the supplied rimpull in the second gear is 273.6 into 500 horsepower into 0.8 divided by the speed in the second gear is 14 kilometer per hour. Similarly speed in the third gear is 21 kilometer per hour, speed in the top gear is 36 kilometer per hour. So, correspondingly you can find the supplied rimpull in all the gear.

$$Maximum\ power\ from\ engine\ = \frac{273.6\ \times\ hp\ \times efficiency}{Speed\ (km/hr)}$$

$$Supplied\ rimpull\ in\ 1st\ gear\ = \frac{273.6\ \times 500\ \times 0.8}{6\ (km/hr)} =\ 18240.00\ kg$$

$$Supplied\ rimpull\ in\ 2nd\ gear\ =\ \frac{273.6\ \times 500\ \times 0.8}{14\ (km/hr)} =\ 7817.14\ kg$$

$$Supplied\ rimpull\ in\ 3rd\ gear\ =\ \frac{273.6\ \times 500\ \times 0.8}{21\ (km/hr)} =\ 5211.43\ kg$$

$$Supplied\ rimpull\ in\ top\ gear\ =\ \frac{273.6\ \times 500\ \times 0.8}{36\ (km/hr)} =\ 3040.00\ kg$$

So, one thing you should note that the maximum usable rimpull based on the coefficient of traction is 26,600 kg. Your usable rimpull the maximum power from the engine is 18240 kg in first gear. So, this is less than the rimpull determined based on the coefficient of traction. So, in this case obviously slippage of the machine would not occur. So, because there is sufficient traction and your usable rimpull will be this one.

So, you have to compare this value with this value with a usable rimpull based on coefficient of traction. So, in this case, since the rimpull from the engine is lesser, we will go by this value only. Now, the horsepower rating is determined based on at standard condition, standard temperature and pressure as we discussed earlier. Variation in temperature and the pressure will affect the efficiency of machine because all the horsepower rating done by the standard organization is it standard conditions of temperature and pressure.

In this case the problem it is given that the machine is working at a higher altitude say it is working at 600 meter. So, with increasing altitude as you very well know. The density of air will reduce. So, the ratio of fuel to air which is needed for the combustion will get affected for an internal combustion engine machine the combustion process should be efficient for that we need to maintain the fuel to air ratio. So, with higher altitude this efficiency gives this ratio fuel to air ratio gets affected. That is why for naturally aspirated machines, the efficiency of the machine will lesser at higher altitude, we have to take it into account when you deduct the rimpull.

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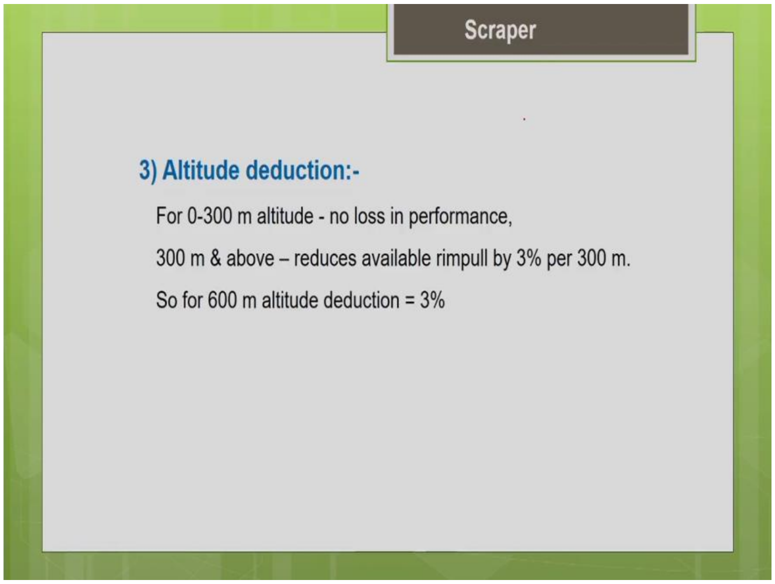

So, it is given to the manufacturer, that for 0 to 300 meter altitude, there is no loss in performance. So, beyond 300-meter altitude for every 300 meter, there will be 3% reduction in the rimpull. So, the available rimpull reduces by 3%. So, in our case, the project site is at 600 meters altitude. So, for the first 300 meter no loss. So, for the next 300 meters we are going to deduct it by 3%, 3% reduction in the available rimpull we have supposed to do.

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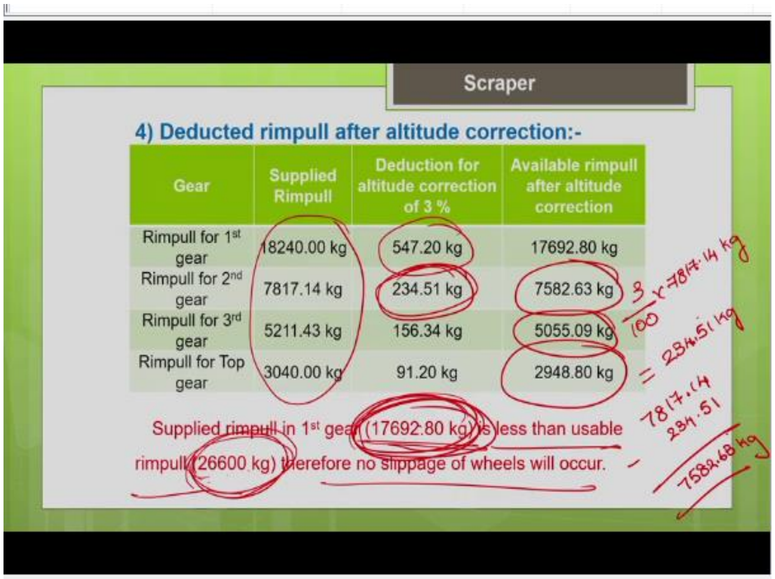

So, that is what is done here, this is your supplied rimpull. For different gear and the deduction for 3%, you calculate 3% of the available rimpull 18,240, this gives you the values is 547.2 kg. So, this much I have to deduct it from 18240 - 547.2. So, this gives me the value as 17,692.8 kg. So, this is my available rimpull after doing the altitude correction for the first gear. Similarly do it for the second gear.

Second gear it is going to be 3% of 7,817.14 kg, this gives me the value is 234.51 kg now, you are going to subtract this from this 7817.14 - 234.51 kg this gives me the value as 7,582.63 kg. So, I have deducted the rimpull according to the altitude. So, this is the available rimpull for the second gear after the altitude correction. Similarly, do it for the third gear and the top gear. So, one thing to be noted is the supplied rimpull is 17692.80 kg is lesser than the usable rimpull derived based upon the coefficient of traction.

So, based on coefficient of traction we have found the maximum usable rimpull is 26,600 kg. So, based upon the rimpull based on the engine power, so, we have found that it is 17692. So, this is less than this. So, now, the actual available rimpull is going to be 17,692.8 kg. The usable is 17,692.8 kg and then there would not be any slippage of the wheel. So, because it is less than 26,600 kg, there is sufficient coefficient of traction.

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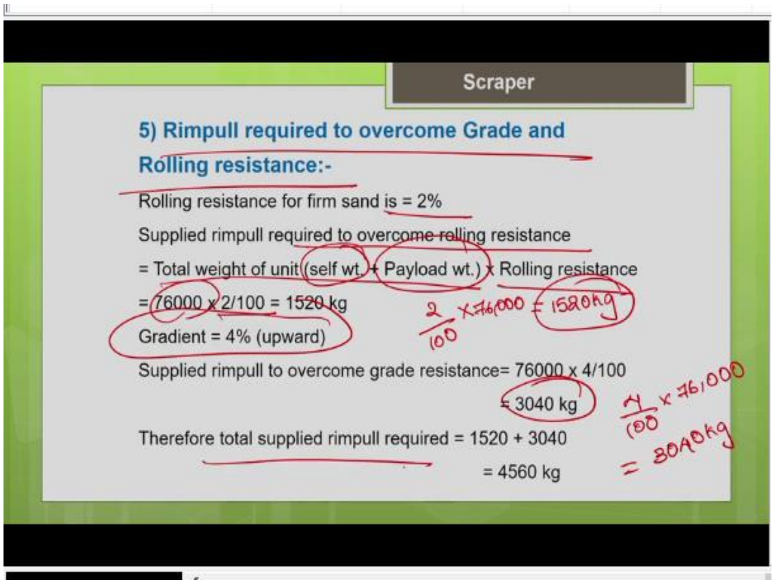

Now, that we have determined the available rimpull based upon the horsepower of the engine given by the manufacturer and after the based upon the project site location that is altitude we have done the altitude correction and after doing the altitude correction what is the available rimpull we have determined. Now, we are going to find what is available rimpull after correcting for the underfoot conditions of the project site. So, as we discuss earlier, we need some rimpull to overcome the resistances in the project site, rolling resistance and the grade resistance.

So, what is the required rimpull to overcome the grade resistance and the rolling resistance? That is what we are going to see now, the rolling resistance for the firm sand is given as 2% of the gross weight of the machine. So, the supplied rimpull required to overcome the rolling resistance is 2% 2 by 100 into the total weight of the machine gross weight, self weight plus a payload, there is nothing but 76,000 kg given in the question.

So, 2 by 100 rolling resistance is 2% of the gross weight 2 by 100 into 76,000 gives you 1520 kg. So, this much power is needed to overcome the rolling resistance. Similarly, the gradient is given as 4%. So, how much power is needed to overcome the grade resistance 4 by 100 into the gross weight of the machine 76,000 kg that gives me the value as 3040 kg. This much power is needed to overcome the grade resistance.

So, what is the total supplied rimpull required to overcome the grade resistance is 1520 + 3040 gives you 4560 kg. This is the total power needed to overcome the resistances in the project site. As we discussed earlier, what is the power available for towing the load. So, that we can know only after determining the required power for overcoming the resistance. So, from the available power generated based on engine, we have to detect the required power needed to overcome the grade and the rolling resistance, only the remaining power will be available for towing or pulling a load.

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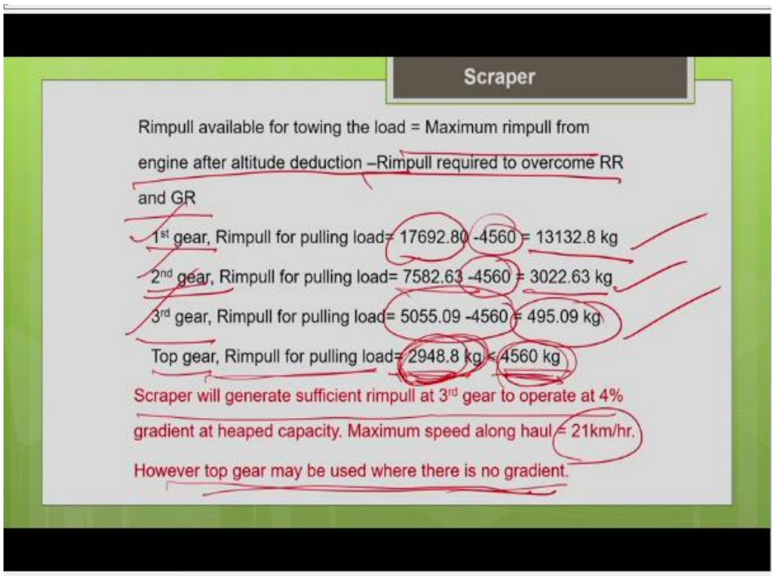

So, the rimpull available for towing the load is the maximum rimpull from the engine after the altitude deduction minus the rimpull required to overcome the rolling resistance grade resistance for the first gear. So, after the altitude after the altitude correction the available rimpull is 17,692.8. Hope you remember 17,692.8 minus the rimpull needed to overcome the rolling and the grade resistance is 4560 kg. So, you deduct this you will get what is the power available for pulling a load or towing the load for first gear.

Similarly for the second gear you know, what is available rimpull after the altitude say after the altitude deduction, this is a power available for the second gear 7,582.63. So, the power needed to overcome the rolling and grade resistance 4560. This is the remaining power available for pulling the load in second gear. Similarly, for the third gear 5055.09 is the power available in the engine - 4560 gives you the remaining power available for pulling the load at third gear.

Rimpull available for towing the load = Maximum rimpull from engine after altitude deduction – Rimpull required to overcome RR and GR

1st gear, Rimpull for pulling load= 17692.80 -4560 = 13132.8 kg
2nd gear, Rimpull for pulling load= 7582.63 -4560 = 3022.63 kg
3rd gear, Rimpull for pulling load= 5055.09 -4560 = 495.09 kg
Top gear, Rimpull for pulling load= 2948.8 kg < 4560 kg

Top gear you can see the power available is minimum 2948.8 kg. So, one thing to be noted is in the Top Gear, the power available the power generated by the engine is lesser than the power needed for overcoming the resistance rolling in the grade resistance. That is why we can not use the top gear when you climb the grade. So, top gear can be used when there is no gradient, but when you are climbing up the grade you cannot use top gear.

That is what we have found out in this problem. The rimpull is not sufficient in the top gear and when you climb up the gradient. Because the rimpull available is lesser than the rimpull needed to overcome the grade in the rolling resistance, but you can use a top gear when you are not climbing the gradient, but in this project is given, we have to climb the 5%. Hope you remember the gradient percentage is given gradient percentage is say 4%. So, we have to climb the gradient the 4%.

So, in this case, we cannot use the top gear when you climb up the grade. So, scraper will generate sufficient rimpull at the third gear. First gear it is sufficient, third gear is sufficient, the second gear it is sufficient. So, the maximum speed possible will be 21 kilometer per hour. That is in the third gear. So, the maximum speed possible is 21 kilometer per hour. Top gear may be used only when there is no gradient in places where there is no gradient.

So, the conclusion is the rimpull sufficient for the different gears first gear, second gear and third gear, only for the top gear it is not sufficient.

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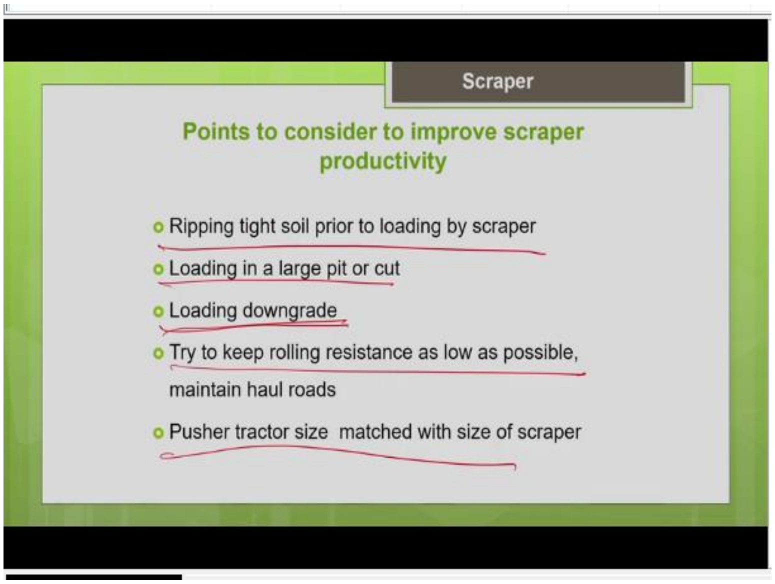

Now, let us see some basic guidelines how to enhance the productivity of the scraper? So, basically the scraper will give you maximum productivity when the soil is in loosened condition. So, that is why it is always advisable if you are going to handle a very hard terrain, like clay harden clay, in that case you have to go for a bulldozer with a ripper attachment, rip it first, loosen it, then use a scraper. Thereby you can enhance the productivity of the scraper.

Ripping tight soil prior to loading by the scraper. Then if you go for loading in a larger pit that will also enhance productivity it can reduce the congestion also and waiting time. Then we can load it downgrade when there is an option to use a downgrade for loading it is preferable to go for downgrade loading as it will reduce the cycle time and increase productivity. Try to keep the rolling resistance of the haul route as low as possible.

How to do that? You have to maintain the haul route, put some efforts for maintaining the haul route using a grader or a bulldozer a to avoid the deep pits, so that it will reduce the rolling resistance and reduce the cycle time and also extend the lifetime of machine. Select the pusher because conventionally what we use is a pusher a loaded scraper. So always choose a pusher size compatible with the size of scraper it should match.

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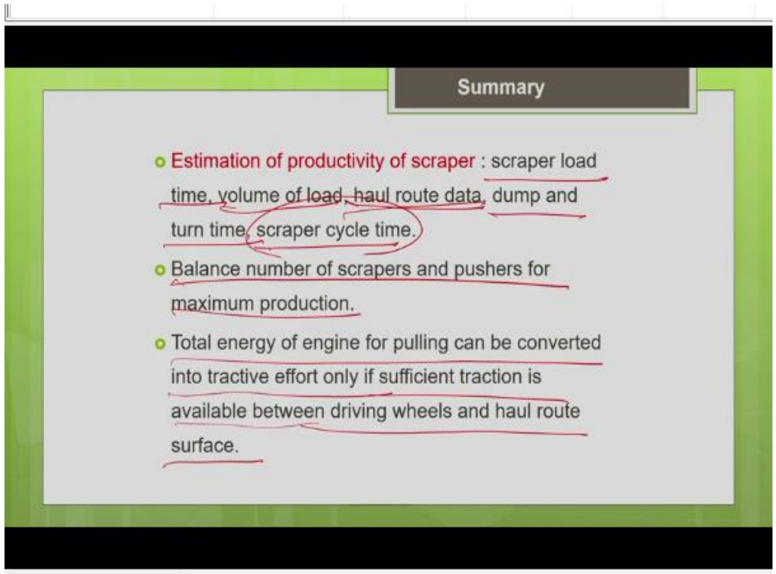

So, we have come to the end of this lecture. Let me summarize what we learned so far. So, we discuss how to estimate the productivity of the scraper. So, we need to determine the scraper loading time first, the optimum loading time from the load growth grow. You can get it from the manufacturer based on the loading time you can find the volume of the load, then if you know haul route data that is the distance and the rolling resistance and the grade resistance in different sections of your haul route.

Then you can find the haul time and the return time, then you need to find the dumping time and the turning time. So, all these things will help you to calculate the scraper cycle time. So, then you have to calculate the pusher cycle time based upon the loading method which we are going to follow we have discussed about different loading methods backtrack loading, chain loading, shuttle loading. So, according to that you have to find the cycle time of the scraper and the cycle time of the pushup.

Now, you balance the number of scrapers and the pusher. So, that there is minimum waiting time and the production will be maximum. So, and also you should always keep in mind that the amount of energy, amount of engine power that can be converted into usable power depends upon the coefficient of traction between the wheel and the ground. Only if there is sufficient traction, most of the engine power will be converted into usable power.

So, the total energy of engine for pulling can be converted into tractive effort only if sufficient traction is available between the driving wheels and the haul route surface and we have worked out the problem to estimate whether the rimpull is sufficient for the particular scraper for doing the desired job. So, with this, I will conclude this lecture, these are the references which I have referred for this lecture.

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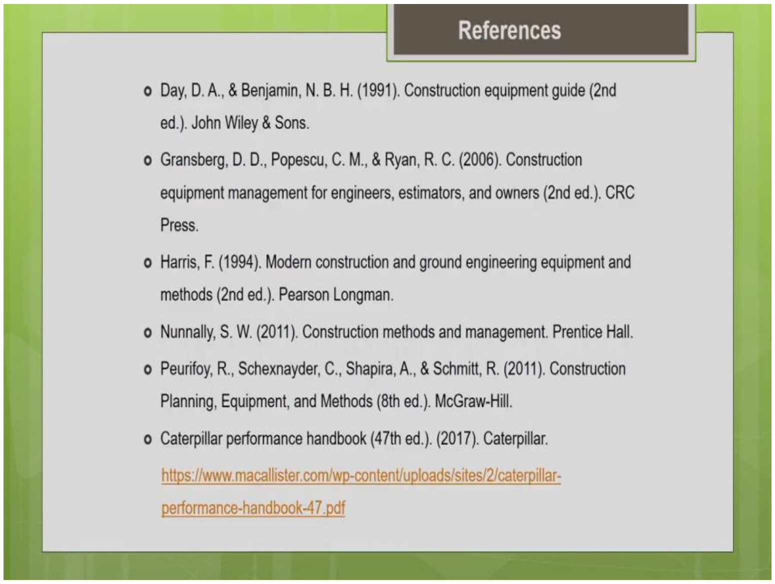

So, we shall meet in the next lecture. The next lecture we will be discussing about the front end loaders. So, what are all the different attachments for the loaders and how to estimate the productivity of the loaders. So, we will be discussing that in detail. Thank you.