Construction Methods and Equipment Management
Prof. Dr. Indu Siva Ranjani
Department of Civil Engineering
Indian Institute of Technology-Guwahati

Lecture-11
Earth Moving Equipment-Scrapers (Part-1)

Hello everyone, I welcome you all to the lecture 11 of the course construction methods and equipment management. In this lecture on the series of earthmoving equipments, in today's lecture we are going to discuss about the scraper.

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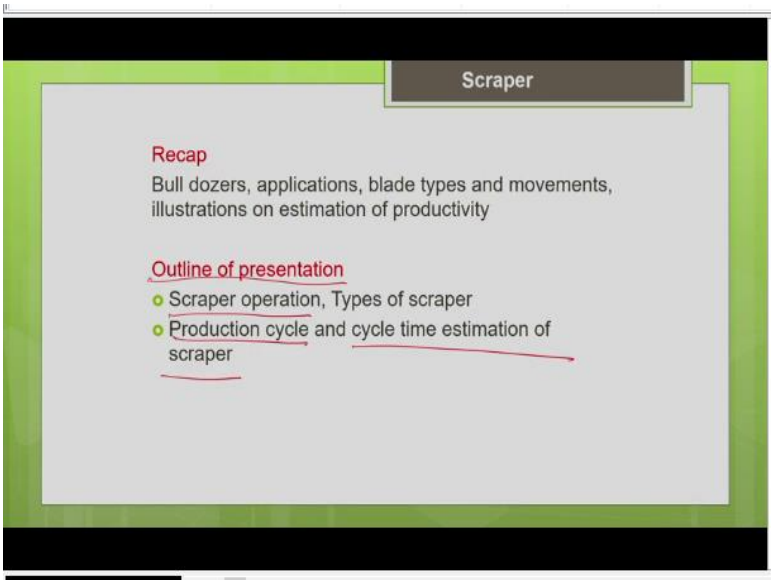

In the previous lecture, we have discussed about the bulldozers, the applications of bulldozers, the blade types and the possible movements of the blade of the bulldozers and how to quantify the performance of the blade and what are the factors which affects the productivity of bulldozers, then we even worked out some illustrations on how to estimate the productivity of the bulldozer?

So, let us see the outline of today's presentation. In today's presentation, we are going to discuss about the operation of scraper. So, what are the basic operating parts of the scraper and what are all the different types of scraper and their applications? So, I will also introduce to you what are all the components of the production cycle of the scraper and how to estimate the cycle time of the scraper? So, these are the things we are going to discuss in the lecture today.

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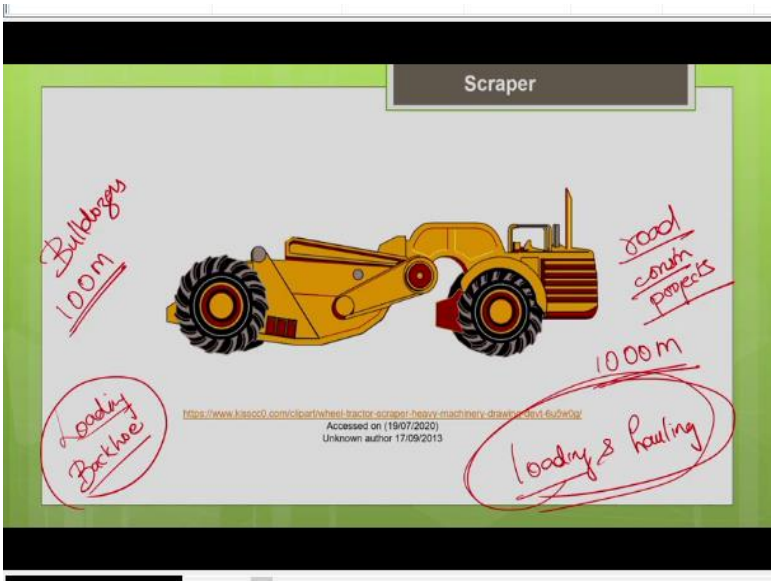

I hope most of you might have seen the scraper. So, this is a picture of the scraper. This scraper basically it is used for medium to long haul distances, say up to 1000 meters you can commonly use the scraper. So, very commonly you can see its application in the road projects, road construction projects, you can see this application of the scraper. Commonly it is used in the foreign countries, but India we cannot very commonly sees this, the scraper.

So, the main advantage of this scraper is it is both good in loading as well as hauling, loading and hauling. So, I hope everyone knows what is loading. It is nothing but cutting the earth and loading a bowl of bucket whatever. So, that operation we called it as loading. There are certain machines which are very good in loading. Say for example, your loaders, your backhoes, excavators. So, they are very good in loading, but their mobility is very much less.

So, that means their economic haul distance for those machines very commonly less than 100 meter. So, for the bulldozer what we discussed in the earlier lecture, the economic haul distance is only up to 100 meter for the bulldozers. So, what I am trying to say here is there are certain machines which are very good in loading, but their mobility is less that means they are not good in hauling. So, they have a haul distance of maybe less than 50 meter or less than 100 meter.

But there are certain machines which are very good hauling like a trucks, but they are not good at loading, but the advantage of this machine is it is good in both loading and hauling. So, it is something between loading and hauling that means, so, I cannot compare the loading efficiency of a scraper with an excavator. So, when you compare it with an excavator, the scraper loading efficiency is less.

Similarly, I cannot compare the hauling efficiency of a scraper with a truck. In that case, the hauling efficiency of a scraper is going to be lesser than the truck. But it is something in between the loading machines and the hauling machines but it is good at both loading and hauling. So, that is the advantage of this machine that makes it more versatile for so many applications. Because it is good both in loading as well as in hauling.

Say for example in your project site, if there is a temporary breakdown of a loading machine. So, but if you have a scraper, then in that case your entire work will not come to a standstill. Similarly, if there is a breakdown of your hauling machine. So, if you have a scraper, it would not stop the entire work. Your work will keep progressing because this machine can take care of both loading as well as hauling.

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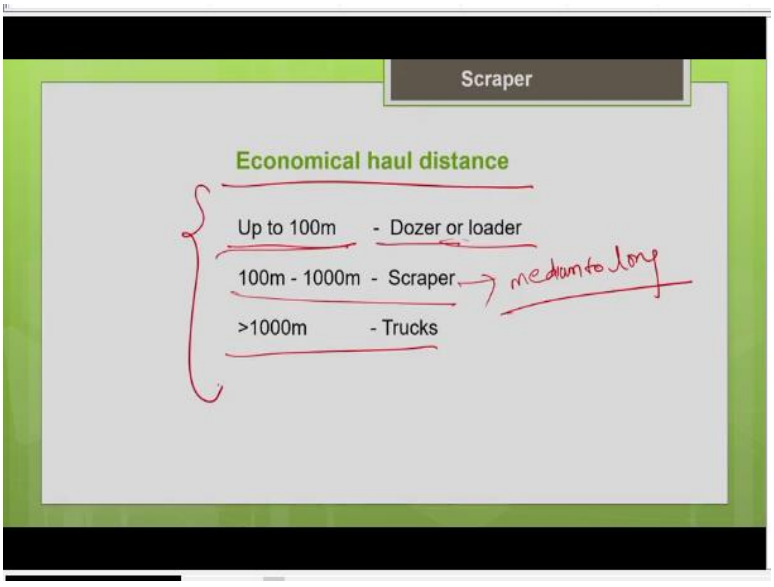

So, when we select the earthmoving machines, we are very much concerned about the economic haul distance of the machine that is a very important parameter. So, based upon that only we have

to select the earthmoving machine. Say the bulldozers what we discussed earlier, it has a hauling distance up to 100 meter. So, beyond 100 meters, it is not economically feasible to use this machine.

Similarly, front end loader, if it is going to be crawler mounted and we can have a haul distance up to 100 meter, if it is going to be wheel mounted, it can be even slightly more than 100 meters. Say it can go up to 200 meter, but not more than that. But your scraper you can see the haul distance is a 1000 meter. So, it can be used for medium to long haul distance I can say.

Obviously trucks can have any long haul distance greater than 1000 meter. So, based upon this haul distance only we have to select the earthmoving machine. So, that depends upon your project requirement. Say for example a dam project or a road project where the haul distance requirement is more, your scraper will perform well. So, that will be the right application for this scraper.

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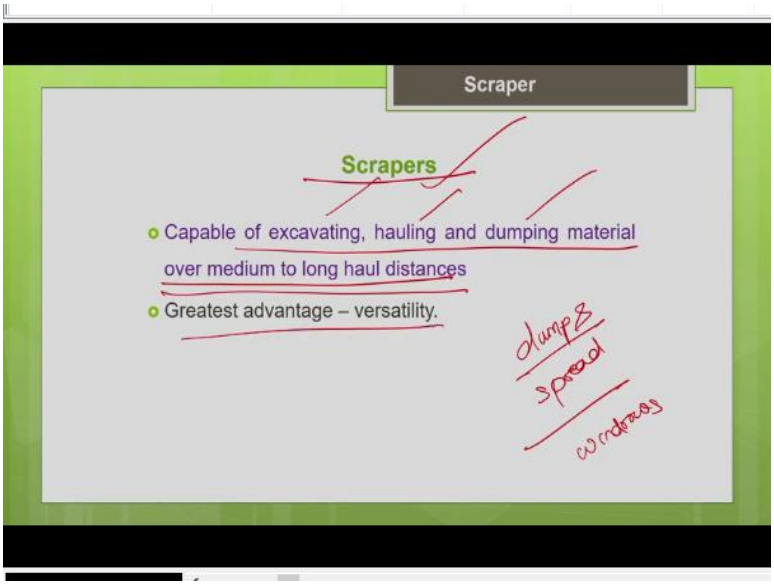

So, the scraper is capable of excavating hauling and dumping material over medium to long haul distances. So, it can excavate, haul as well as dump. So, it can dump and spread the material in continuous operation that is one advantage, it can uniformly dump and spread the material same windrows. So, you can have a uniform spreading of material to required thickness. So, very much suitable for the preparation of subgrade of the roads.

So, another thing is very commonly you can use a scraper and you can see its application for top layers stripping of the soil or the cutting and filling. So, we cut the soil in one place and carry it and fill it in the other place very commonly you can see many construction projects like road projects, cut and fill earthmoving operation. So, this is a very common equipment use for those operations particularly for medium to long haul distances. The advantage of both loading and hauling makes it more versatile for many applications.

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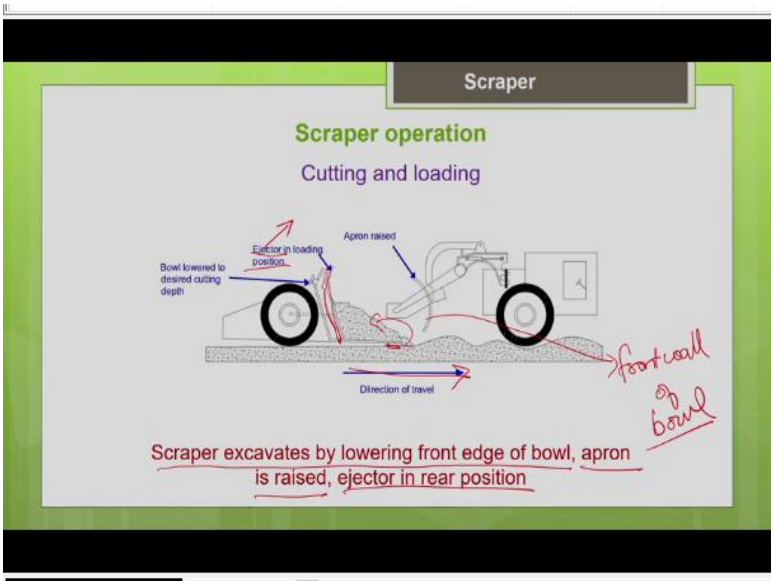

Now, let us see the basic operation of the scraper. So, first of all, we should know what are all the operating parts of the scraper? The scraper has a bowl. So, this is the bowl of the scraper you can see the bowl. So, at the bottom end of the bowl, the frame bottom end of the bowl, this is the direction of travel. At the front bottom end of the bowl, you have the cutting edge. So, cutting edge across the width of the bowl.

So, when you want to do the cutting and loading operation, you are supposed to lower the bowl, lower the bowl, so that the cutting edge is in contact with the ground, once it makes a contact with the ground, it will start cutting the soil and the soil will start entering your bowl. So, to facilitating the entry of material to the bowl, you have to raise this apron, apron is acts like the front wall of the bowl.

So, you can either raise your apron or lower the apron. So, when you want the material in flow, you have to raise the apron. Similarly, when you are dumping it, to facilitate the outflow, you have to raise the apron and now for the loading operation and need to raise the apron. So, as the material can enter into the bowl and there is one more important part called is ejector. So, this ejector is in the rear end of the bowl, you can see this is in the rear end of the bowl, it can either move forward or backward.

So, when you are doing the loading operation, it has to be at the rear end of the bowl. So, the scraper excavates by lowering the front edge of the bowl, that is a cutting edge apron is raised and the ejector should be in the rear position. As the name indicates ejector means it helps in ejecting the material out of the bowl. So, we are going to move this ejector forward when you want to dump your material.

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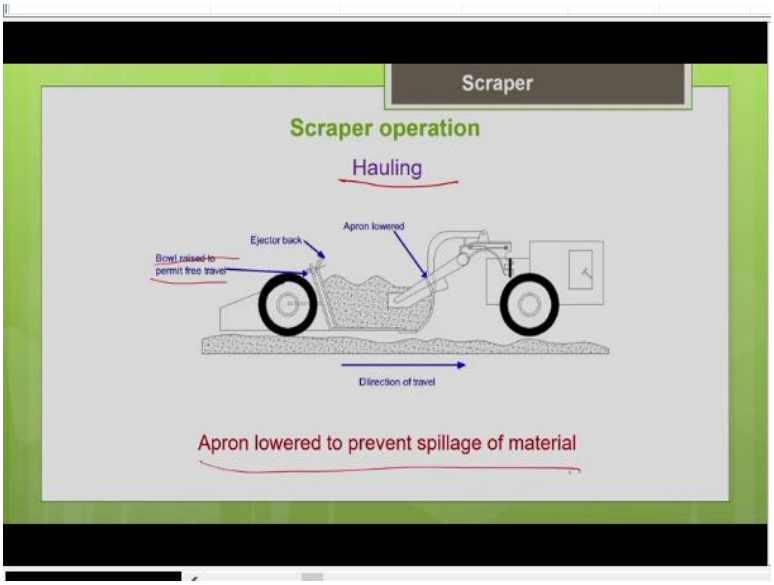

So next is hauling, once your bowl full, so now you can just raise your bowl and you have to just carry the material in the bowl. You are going to haul it. So, the bowl is raised, so that you can permit free travel of your machine. So, now also you can see the ejector is in the rear end only. Now you are lowering your apron. So, why should we lower the apron so that we can avoid the spillage of the material out of your bowl. So, the apron is lowered to prevent the spillage of materials during the hauling operation.

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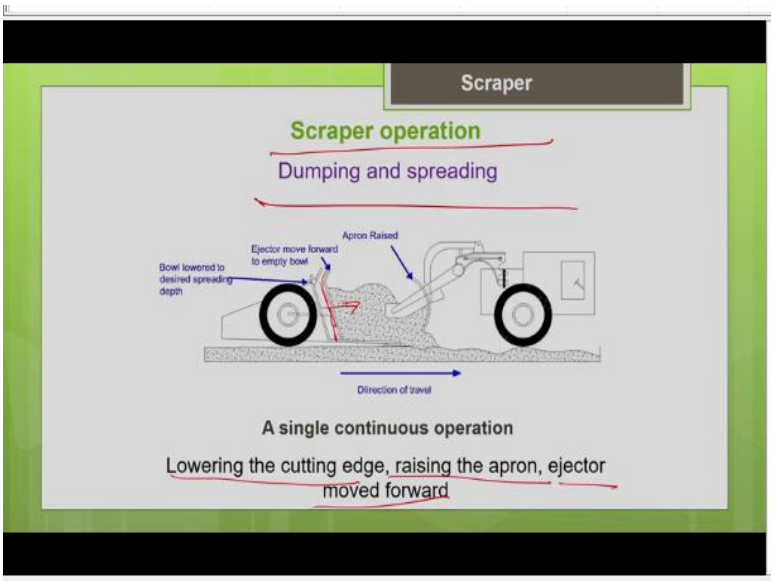

So, after hauling once you reach a dumping place your filling place, now you have to dump the material. So, now you again raise an apron to facilitate the outflow of the material. Again, lower the cutting edge, lower the bowl, now raise the apron, you are going to facilitate the outflow of the material, you have to move your ejector forward. So, this is an ejector, you move it this ejector, you have to move it forward as you slowly move it forward you can eject the material out of the bowl.

So, that you can do the dumping and spreading in one operation, one step I can do it. I can uniformly spread the material in windrows or spread it in uniform layers of required thickness, that is one advantage of this scraper. Dumping and spreading can be done in one step. So, you are going to lower the cutting edge, raise the apron and ejector is moved forward. So, that you can facilitate the out flow of the material out of the bowl. So, this is about the scraper operation.

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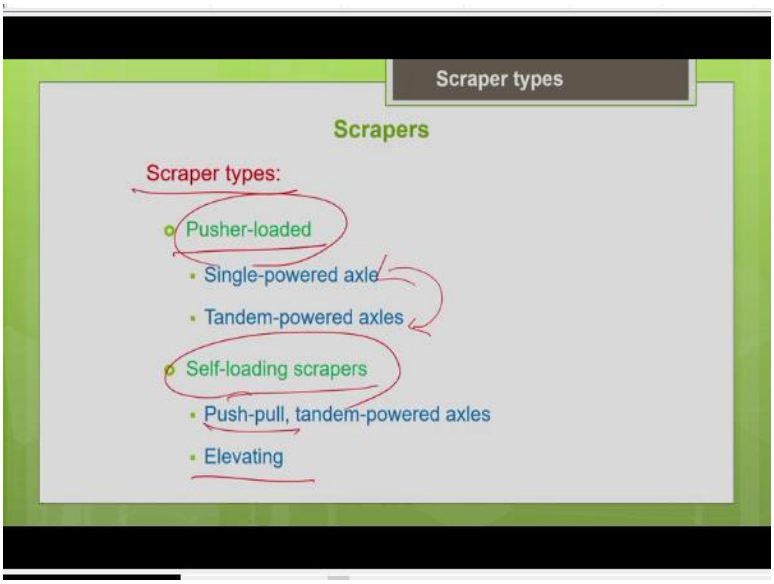

Now let us discuss about the types of the scraper. So, there are different types of scrapers. So, in this we have classified based on whether the scraper needs assistance from the other machines during its loading operation or not based upon that we have done this classification. Pusher loaded means that scraper needs the assistance of a pusher or a tractor or a bulldozer during its loading operation, those scrapers are called as pusher loaded scrapers.

So, there are certain scrapers which are self loading in nature. That means it does not need the assistance of other machines during its loading operation. That is why they are called as self loading. So, we can classify the pusher loader into single power axle and tandem power axle, we are going to discuss that in the upcoming slides. Similarly, self loading also there are different types, push-pull and elevating. So, we are going to discuss all these types of scrapers in detail in the upcoming slides.

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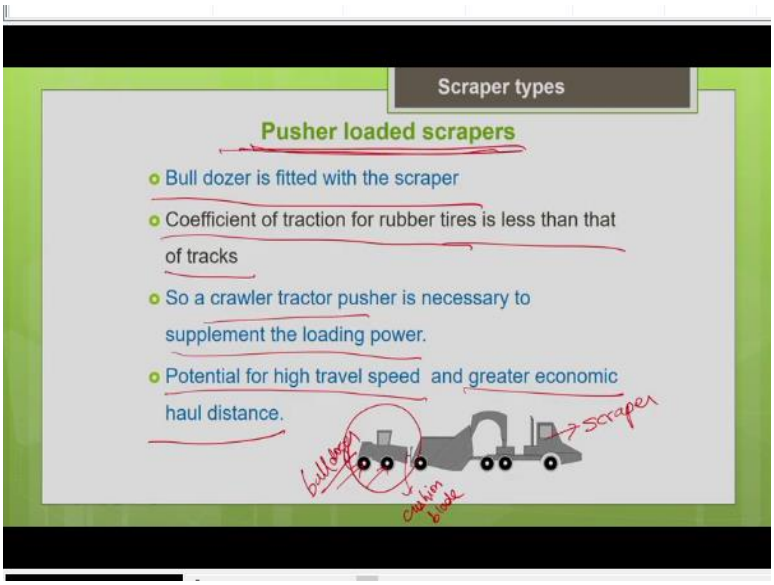

So, now first let us see what are pusher loaded scrapers? So, I have shown the schematic sketch earlier, this is your scraper machine which is leading. The trailing one is your bulldozer. So, hope you remember what type of blade you will fix for assisting other machines. So, you are using a cushion blade, C blade, C blade is attached to the bulldozer just for pushing or assisting the other machines.

So, you know that the scrapers are tyre mounted, normally wheel mounted machines. So, for the wheel mounted machines, the tractive effort generated will be lesser when compared to the crawler or track mounted machines. So, the coefficient of traction will be poor. So, the amount of tractive effort generated will be less for the wheel mounted machines, to supplement the loading power of this wheel mounted scraper you can take the help of a crawler mounted or track mounted bulldozer.

In this picture I have shown you the wheel mounted bulldozer you can still go for crawler mounted bulldozer, so that it can still increase the loading power of the scraper. So, the main thing is fitting the scraper with the bulldozer here, you know that the coefficient of traction for the rubber tyre is less than that of tracks. So, we are taking the help of the crawler tractor pusher to supplement the loading power of the scraper.

So only when the scraper is cutting the earth and filling its bowl that is during the loading operation I need the help of the pusher. Once a bowl is completely filled, your pusher can be detached from

the scraper and the scraper can haul the material by itself. So, we need the assistance of the machine only during the loading operation, but taking the help of the pusher I am able to reduce the cycle time of the scraper because the loading time gets reduced and also I can increase the productivity of the scraper.

So, basically all conventional scrapers are pusher loaded scraper. So, they have the potential for high travel speed because power is supplemented with the help of the pusher and also the economic haul distance is also higher relatively higher for this kind of pusher loaded scraper.

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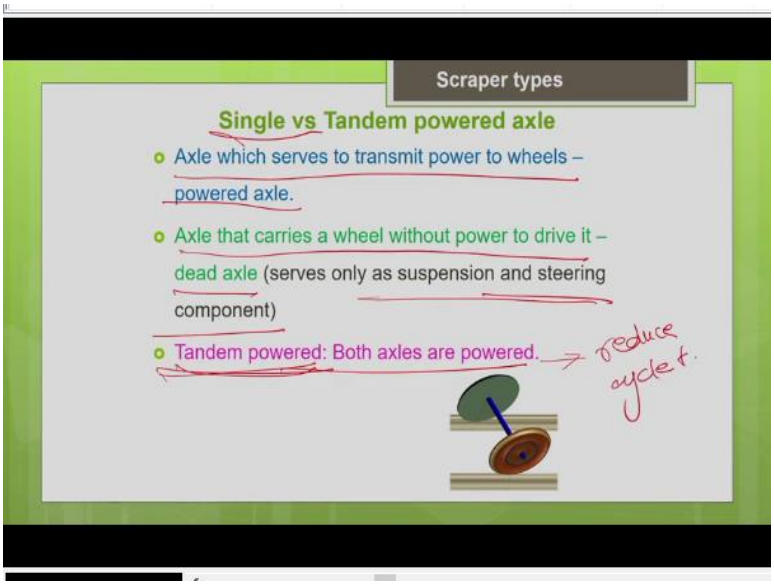

So, now let us see what are these are single versus tandem powered axle scrapers? So, axle basically how do you classify the axle into powered axle and dead axle? See in our common vehicle say for example car, so you know that it may not be the case like all the axles are powered. So, maybe we only one axle may be powered the other axle we just dead ok powered in the sense the powered axle will transfer the power to the wheel those wheels are called driving wheels.

So, the other axle will be just dead axle which would not transfer the power to the wheel, it will just act like a steering component. So, the axle which serves to transmit the power to the wheel is called a powered axle, the axle that carries a wheel without power to drive it, it is called as it dead axle, they are just acting like a suspension steering component. So, in the construction equipment

you can say for the machines which are operated in very tough underfoot conditions where the rolling resistance is very high.

Say very rocky terrain or muddy terrain. So, very hardened clay terrain or very steep grade where the grade resistance is very high, steeper slopes. In those cases, we have to go for tandem powered that means all the axle should be powered. So, that the power generator will be more. So, tandem power in the sense all the axles are powered, single power means only one axle is powered.

So, how do you make the choice of machine for a project? If your project conditions are very severe, extreme working conditions, poor underfoot conditions, where the resistance is going to be very high in terms of rolling resistance and grade resistance. In that case, you have to go for tandem power machines where all the axles are power which can generate more power to overcome all this rolling resistance. So, that will help a lot to reduce your cycle time and increase your productivity. So, it will reduce your cycle time or increase the speed of your machine.

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So, this is tandem powered axles. So, they have this twin-engine arrangement. So, twin engine arrangement in the sense that they have 2 engines. So, that it can produce this extra power for you. So, this kind of arrangement produces extra power. So, that we can overcome the rolling resistance and high grade resistance. But obviously, because of the twin engine arrangement, its cost is going

to be higher than your single power axle at least 25% the cost is going to be more than your single power axle.

But even though the cost is high it is going to be economical for you for tougher underfoot conditions. Because in your tough underfoot conditions, you can increase your speed of your machine thereby it increases the productivity and reduces your unit production cost. So, that is why I say tandem power is economical for tough underfoot conditions. So, based upon project conditions, you have to make the right choice of your machine.

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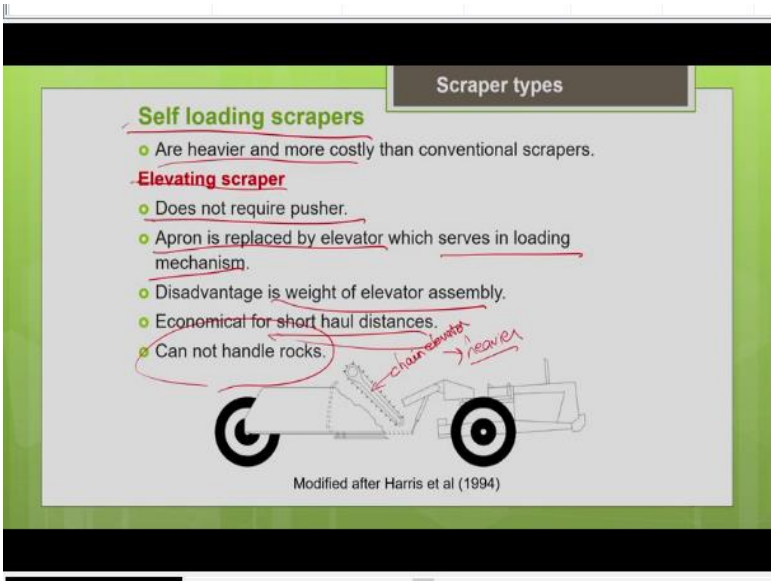

So, next is your self-loading scraper. So, far, we have discussed about the pusher loaded scraper where it needs the assistance of a pusher during its loading operation. In the scrapers it is self loading, that means it can load on its own, it does not need the assistance of another machine during its loading operation. So, but basically these machines are heavier and costlier when compared to a conventional pusher loaded scrapers that is one limitation of this machine.

So, under the self loading, there are different types. So, one such type is elevating scraper. So, elevating scraper, you can see a chain elevator. So, this is your chain elevator assembly, just like the elevator, you can see series of flights kind of steps arranged the elevator chain. So, instead of apron you have this chain elevator, it will facilitate the entry of your material into the bowl. So, as usual you have an ejector, which will help you to dump the material when the dumping is needed.

So, basically this does not require the help of pusher that is why it called it as self loading scraper. Here the apron is replaced by an elevator which helps you to load, but the disadvantage is this chain elevator is heavier, it increases the self weight of your machine. So, this machine is economical only for short haul distances. So, we cannot use it for a very long haul distance like the other type of scrapers.

So, you can use it only for a very short haul distance. And one more thing from material perspective, you have to be very careful this cannot handle rocks, because the bigger size rocks can jam, it can create jam in the chain elevator assembly. So, that is why you should not handle the rocks with this machine, it cannot use the rocky terrain, it cannot be used for handling the rocks.

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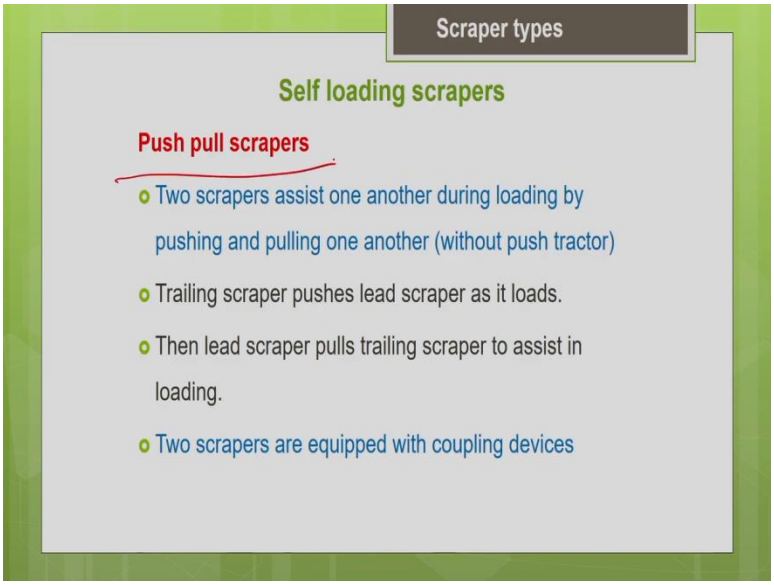

The another type of to self loading scrapers is your push pull scrapers. Here, these machines are not going to take the help of other machine like a pusher. But let us say for example, the scrapers which are employed in a project site. So, they will do a teamwork. Teamwork in the sense if there are 2 scrapers, one is in the leading position, the other one is in the trailing position. See, the one which is in the leading position. So, it will pull the trailing for the scraper when the trailing scraper is doing the loading operation.

Similarly, the trailing scraper will push the leading scraper when the leading scraper is doing the loading operation. So, these 2 scrapers are connected to each other with a coupling device. So, that the scrapers can help each other during the loading operation. So, this is a kind of teamwork, with the help of teamwork, we can get the job done. So, this is basically the mechanism of the push pull scrapers. So, the 2 scrapers are assisting one another during loading by pushing and pulling one another without the help of push tractor.

The trailing scraper which is in the rear end pushes the lead scraper as it loads, it will push it, when the leading scraper is loaded. Then the lead scraper pulls the trailing scraper when the trailing scraper is loading, that is how they help each other. So, that the productivity of the scraper can be enhanced to facilitate this the scrapers are equipped with coupling devices.

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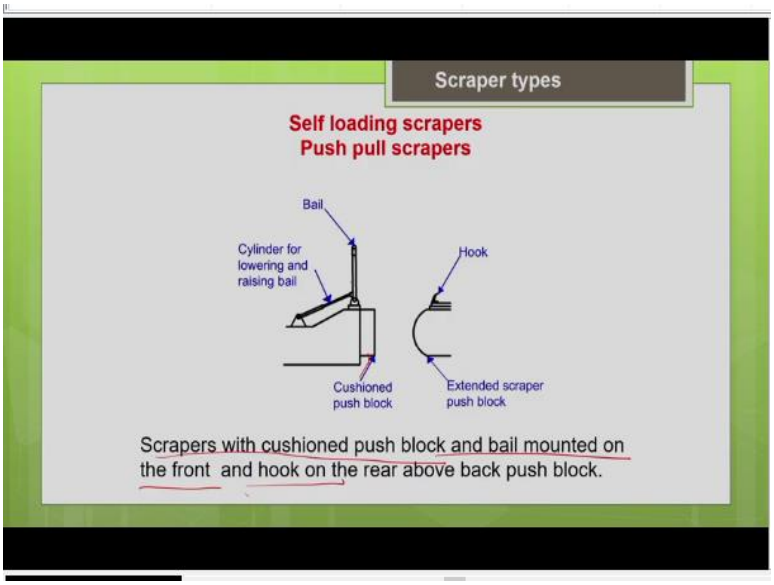

So, you can see the picture. This is a kind of coupling device like the scrapers will be having a cushioned push block, you can see the push block. So, this is also another scraper push block. So, the scraper has this hook and the bail arrangement. Hook and bail arrangement so that you can easily connect one scraper to the other scraper and also this push blocks will facilitate while pushing the when the scrapers are pushing each other.

So, the scrapers are provided with cushion push block and a bail mounted on the front each scraper will have a bail mounted on the front and there will be a hook on the rear end. So, that it can

facilitate coupling of scrapers. So, this hook and bail mechanism can easily facilitate the coupling of 2 scrapers. So, every scraper will have a bail mounted on the front and a hook on the rear end. So, which will facilitate its connection with another scraper.

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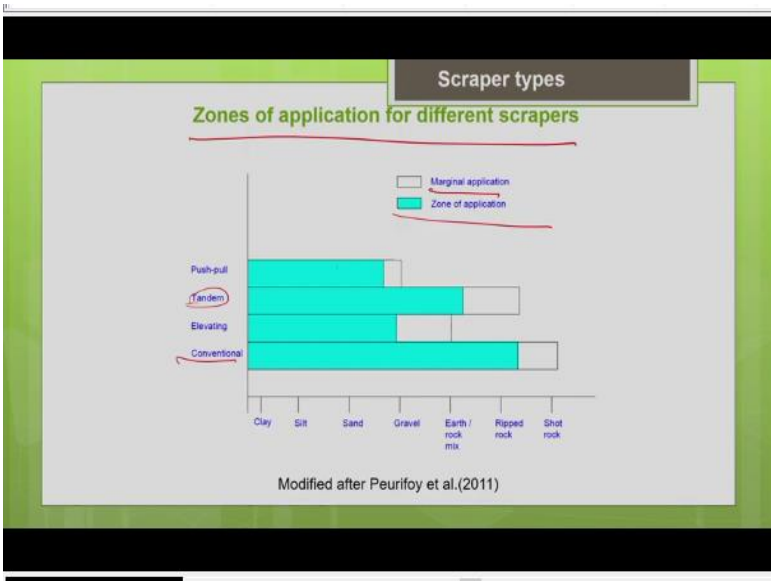

Now, let us see what are all the zones of application of the different scrapers? So, you have to select a scraper based on the type of material in your project site. So, by looking into this picture, you can see this blue color indicates the zone of application and white indicates the marginal application of this particular scraper. So, by looking at a picture, we can see this convention there is a pusher loaded scraper is having a wider zone of application with respect to material type.

So, it can easily handle most of the material you can see, but marginally it can handle the short rock but it has a wider zone of application with respect to material type when compared to other types of scraper. Say this elevating scraper you cannot use it comfortably when handling rocks, you can see that. So, comfortably you can handle when we till gravel even the push pull scrapers it cannot easily handle the rock.

So, when we go for tender over we can generate more power, you can see this slightly, the performance is better when compared to the other 2 types, but among all the type of scrapers your pusher loader scraper is showing the best performance with respect to the range of material you

can see, it can handle most of the materials comfortably because of the supplemental loading power obtained with the help of the pusher.

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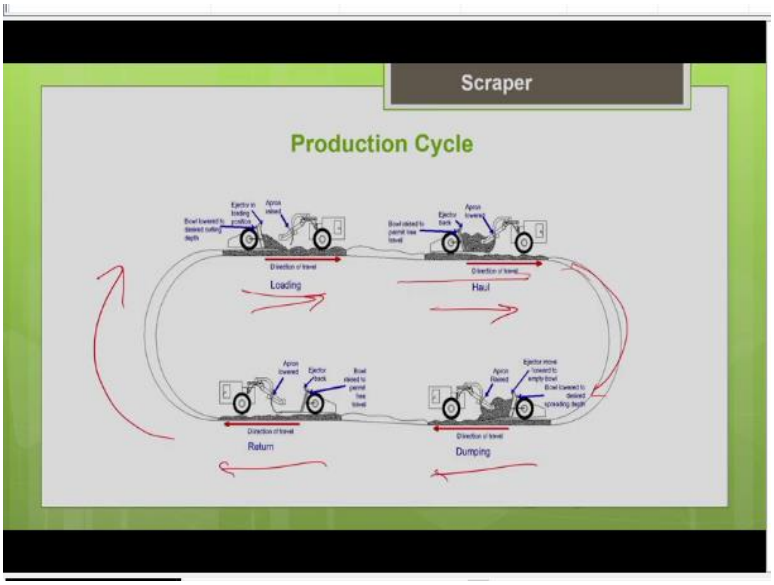

Now, let us see what is it a production cycle what are all the components of the production cycle of a scraper? So, you can see the scraper has to first do the loading operation first, cut the earth and fill the bowl. Once the bowl is completely filled, you will just raise the bowl and haul the material, haul it till it reaches the dumping site. So, in this, picture it will show it is turning first, it is turning then it is dumping it varies from project to project in some cases it has to dump and then make a turn it depends upon your project site constraints.

Then here it is turning then it is dumping. The dump area or the fill area and spreading it to the required thickness as needed. Then, when the bowl is empty, it is just returning return a haul in the unloaded condition. Now again, turning, so I am getting ready for the next cycle. So, in this production cycle, you can see there are 2 turnings involved. So, depending on your project site there can be even more number of tunings than this, everything depends upon your project site. So, basically loading, hauling, your turning, dumping, returning again turning and get ready for the next cycle. So, these are the components which makes up the production cycle of a scraper.

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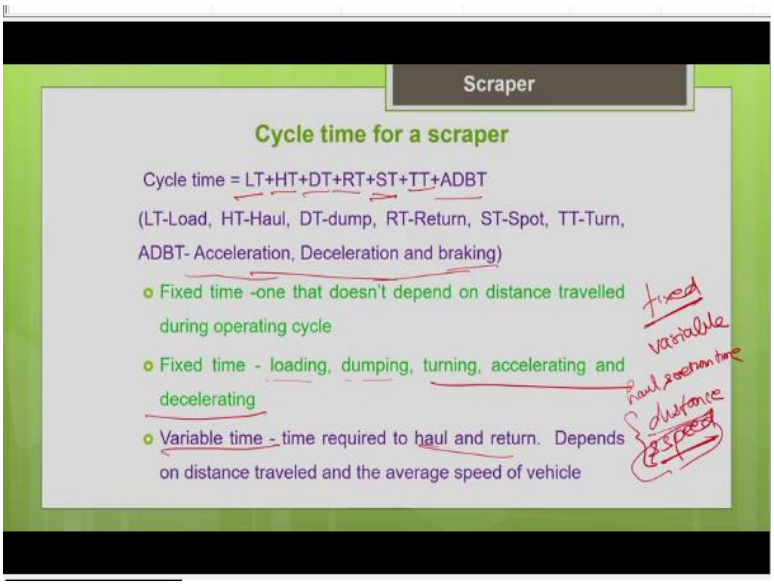

Cycle time = LT+HT+DT+RT+ST+TT+ADBT

(Where, LT-Load, HT-Haul, DT-dump, RT-Return, ST-Spot, TT-Turn, ADBT- Acceleration, Deceleration and braking)

So, cycle time of a scraper, it is nothing but load time, hauling time, dumping time, return time spotting because most of the conventional scrapers a pusher loader scraper. So, it has to spot the pusher, that spotting time is also included then turning, then ADBT that means the time needed for increasing your speed or decreasing the speed, time needed for applying the brakes. So, all this manure comes under this ADBT acceleration deceleration and the braking.

So, basically you can split the cycle time into 2 parts. One is fixed time, other one is variable time. Fixed in the sense this part of the cycle time does not depend upon your travel distance. So, that is called as fixed time, say your loading, dumping, turning, your accelerating, decelerating. All these things comes under the fixed time. So, it is not dependent upon the distance travelled. The other one is a variable time, your haul and return is a variable time because it is significantly dependent on your travel distance.

So, your haul and return time depends upon your travel distance as well as the speed of your machine based upon that only you can decide your haul return time, obviously, you know that speed of the machine depends upon your project conditions. So, how is the underfoot condition

rolling resistance and grade resistance and your type of machine everything is going to affect the speed of machine. Now, let us see what is the loading time?

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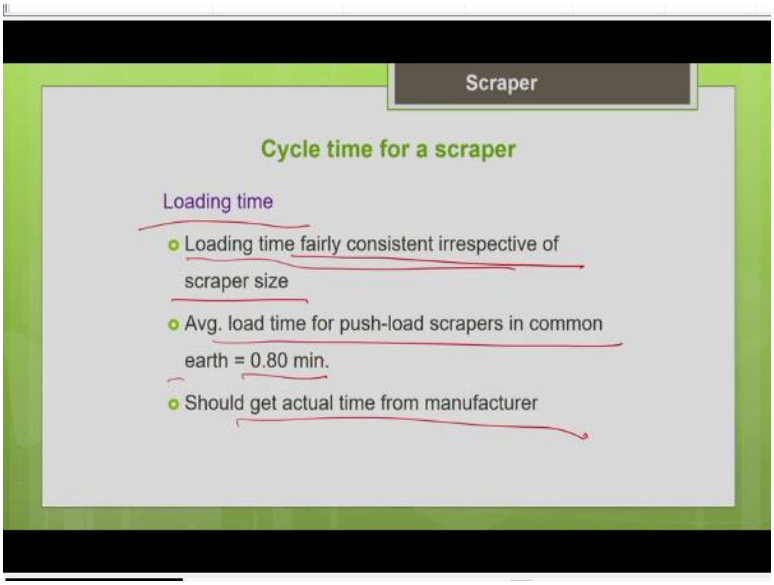

So, basically the loading time of the scraper is fairly consistent irrespective of the scraper size. So, that means whether it is going to be a smaller scraper or bigger scraper in both cases. So, commonly we can say that we are going to assist this scraper with the help of a pusher according to the size of the scraper the compatible size of the pusher you have to select and we are going to supplement the loading power.

So, that is why the loading time is going to be fairly consistent, irrespective of the scraper size whether it is a smaller one a bigger one since it is going to be assisted with the pusher the loading time would not change much. So, you can take the loading time actual time from the manufacturer for the particular scraper and the for the particular material. So, we can take it from the manufacturer.

The average load time for the pusher loaded scraper in common earth. Say for example this typical values given for common earth it is 0.8 minute. So, you can take these values from the equipment handbook hopefully from the equipment manufacturer.

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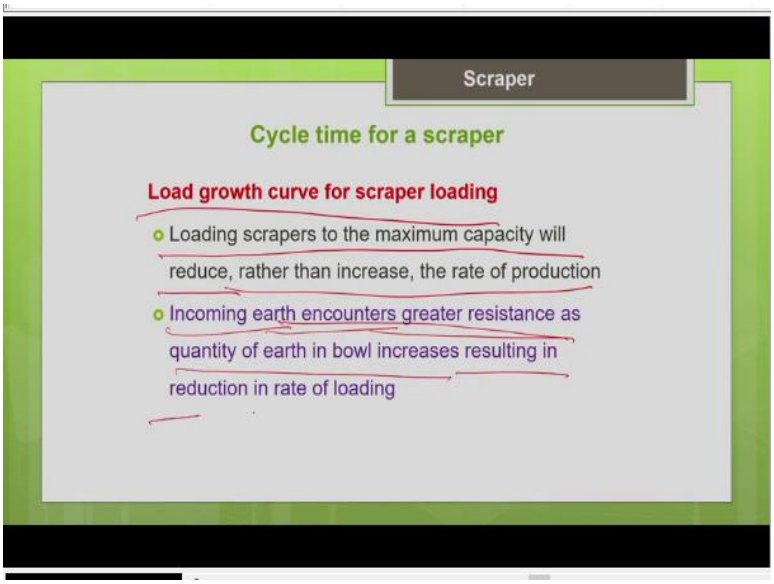

Another important concept which we need to know is about the load growth curve for scraper loading. So, we commonly believed that when we load this scraper when we fill the bowl of the scraper to the maximum capacity we are going to maximize a production. So, this is what is a common belief this is what is a common assumption, but that is not true. So, people have done the studies and they proved that when we tried to load the scraper to its fullest capacity.

So, the production starts reducing beyond a particular time, why that is happening? Because you know that loading mechanism of the scraper hope you remember the scraper loading mechanism. So, the material you are lowering the bowl. So, the material is entering through the apron into the bowl. So, initially when the material enters into the bowl. So, initially when it enters it can easily enter into the bowl? So, say now, when the bowl is almost full say 85% volume of the bowl is filled with the material. Now, you can see that the loading rate will start reducing why?

Because the incoming earth encounters resistance from the material which is already lying inside the bowl. So, the material which is already lying inside the bowl will start offering resistance to the incoming materials, which is entering into the bowl, when the bowl is 80, 85% fill. So, because of that, you can see that the loading rate will start reducing. So, this they call this law of diminishing returns.

So, that is what is written in this slide. The loading scrapers to the maximum capacity will reduce rather than increase the rate of production. So, do not try to load the scraper to its maximum capacity. The incoming earth encounters greater resistance as the quantity of earth in the bowl increases resulting in a reduction in rate of loading. So, the material which is lying inside the bowl, so when the amount of material inside the bowl starts increasing, that will start offering resistance to the material which is trying to enter the bowl now. So, that is why the loading rate starts reducing. So, we can easily understand that concept by drawing this load growth curve.

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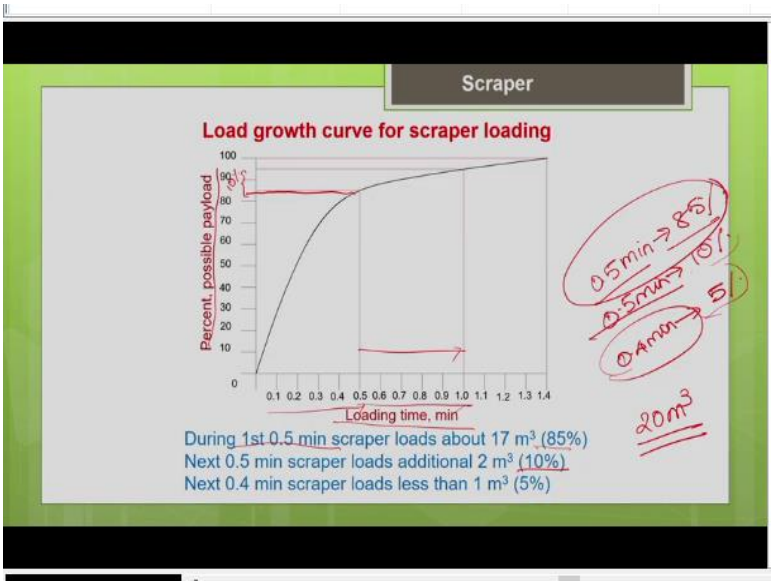

See, you have the loading time in minutes in the x axis and you have the percentage possible payload in the y axis. So, possible payload in percentage means what is the maximum capacity of your bowl? So, how much you actually fill your bowl? So, that percentage will be plotted here. So, now you can say that during the first 0.5 minute say the scraper capacity is 20 m^3. The maximum capacity of the scraper which we have considered here is say 20 m^3.

Now you are loading the material into the bowl for the first 0.5 minute, you can see for the first 0.5 minute. So, your payload percentage is how much you have filled 85%, in the first 0.5 minute I have filled 85% of the scraper bowl, but the next 0.5 minute say till 1 minute you can see how much you filled it only 10%. So, here I have filled only 10% for the next 0.5 minute. So, for the first 0.5 minute, I have filled 85%.

For the next 0.5 minute I have filled only 10% and the next 0.4 minute I am filling only 5%. So, by looking at this values, you can see that beyond 85% beyond 0.5 minute of loading, you can see that the rate of loading is reducing, the rate of loading starts reducing, that is why we have to draw this kind of load growth curves and you have to find the optimum loading time for the particular scraper for the particular material and we have to load the bowl only to that particular capacity.

So, we have to go by only optimum loading time that you can get it from the manufacturer, optimum loading time can be determined from the load growth curve and you can also get the value from the manufacturer. So, this curve clearly shows that only for the first 0.5 minute, you can see that the loading rate is good 85% you have filled, beyond that, your rate of loading has started reducing because the next 0.5 I have loaded only 10%.

And the next 0.4 have loaded only 5%. So, that means that we should not try to load to its fullest capacity, we are actually wasting our time by trying to load it to the fullest capacity. So, find the optimal loading time by drawing the load growth curve.

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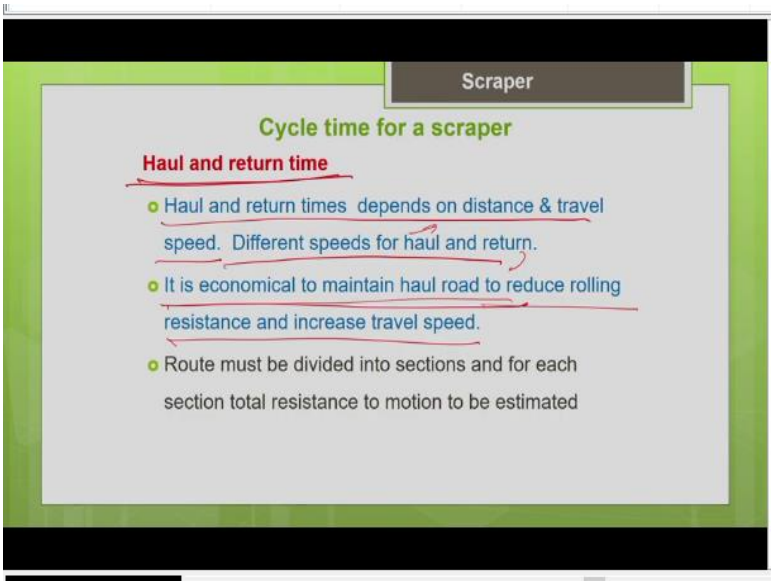

So, the next important component of the cycle time of the scraper is your haul and return time, as I told you it is a variable time, it is going to depend upon your travel distance and the speed of your machine. So, that speed depends upon your project site condition underfoot conditions. So, haul and return time depends upon the distance and the travel speed. So, we can see that obviously,

different speeds are there for the haul journey the return journey onward journey and the return journey.

Because while hauling it is not loaded condition, in the return journey, it is unloaded condition, speed will be higher in the entirely unloaded condition. So, we should know that it is very important to note that we have to maintain the haul route; we have to spend some efforts in maintaining the haul route of the project site. Haul route you have to maintain it either with the help of a grader or a bulldozer, we have to maintain the haul route using water trucks, you have to sprinkle the water and maintain the moisture content in the haul route.

So, that you can avoid or control the dust to improve the visibility of the site, all these things need to be done carefully to maintain the haul route. So, whatever efforts you are putting to maintain your haul route, which will help in reducing the cycle time of your machine, it will help in reducing the haul and return time and that way it will improve the productivity of your machine.

So, it is economical to maintain the haul route. So, whatever efforts, whatever money you spend for maintaining your haul road, it is going to give you good return by saving your cycle time, by increasing your productivity and thereby reduce your unit production cost, it is economical to maintain the haul road to reduce the rolling resistance and increasing travel speed. Sometimes you can see in your project site, different sections of your haul route will have different types of the resistance.

So, the rolling resistance and the grade resistance will differ from section to section in a haul route. In that case, you have to determine the speed of the machine in every section independently. So, individually you have to break the haul route into different sections.

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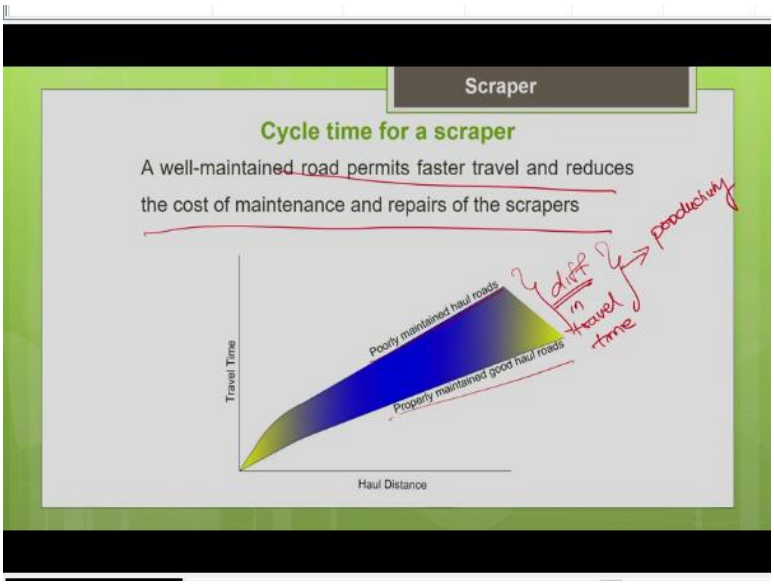

And for every individual section, you are supposed to determine the speed and the travel time. This picture clearly shows like what are the benefits we get by maintaining the haul route. This is just a schematic picture which shows how well maintained road permits faster travel and it reduces the cost of maintenance and the repair of the machine also. If you maintain your haul route, you can increase your life of a machine.

The cost of maintenance and repair that is your operating cost you can reduce and you can also extend your lifetime of your machine. So, there are so many benefits by maintaining the haul route. So, you can see the difference in the travel time between poorly maintained haul routes and properly maintained good haul roads, in properly maintained haul roads, you can see that the travel time is very much less.

So, this much difference or saving the travel time can have a significant effect on your productivity, you can have a significant effect in enhancement of your productivity and the reduction in cost associated.

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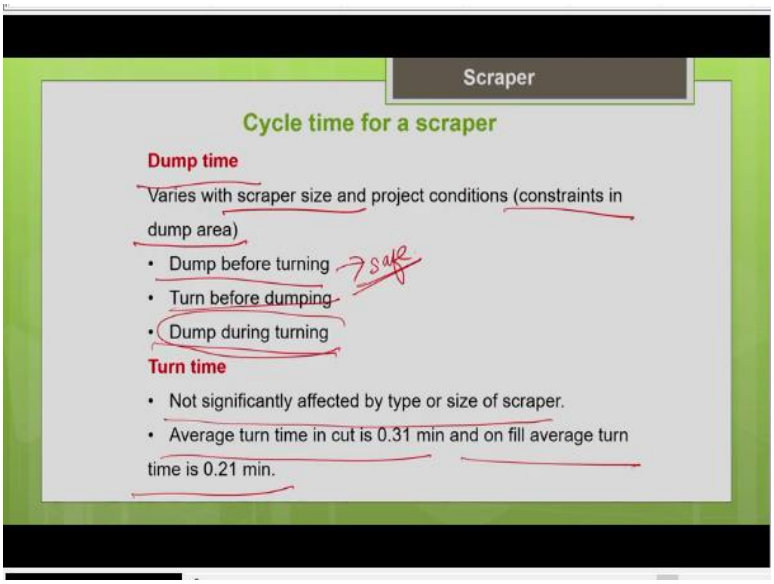

So, the next important thing which we are going to see as a component of your cycle time is your dump time. So, your dump time of your scraper it depends upon your scraper size obviously, bigger the scraper your dumping time will be more. So, it depends upon the scraper size as well as it depends upon the material which it is handling, if it is a loose material. So, it will be very easy for the scraper to dump it loose flowing material.

So, if it is going to be very cohesive sticky material in that case dumping time will be more and also it depends upon the constraints in your dump area. Many times, you can see that the dumping site may be very narrow lot of congestion of other machines can be there the dumping site, in that case your machine has to wait for dumping. So, all these things depending upon the constraints of the dump area, it can affect your dumping time.

And another important thing which you also always need to remember is the scrapers are basically designed for to looser material. So, when you handle loose earth its productivity will be very high. So, that is very, very commonly you can see that if the terrain is going to be very hard terrain so very tough consolidative clay. So, in order to enhance the productivity of the scraper, what they do is initially they use a bulldozer with a ripper and rip the soil.

So, they loosen the earth the rip it, so that you can easily use a scraper for loading operation. So that way you can help the scraper to reduce the loading time. Now we are discussing about the

dumping time. So, you can see that there are different ways to dump in a project site. So, everything depends upon your project site constraints, you can see that sometimes your scraper will dump before turning.

So, it depends upon your project site. So, before turning itself it will dump and this is going to be very safe way because in a loaded condition if it is going to turn in that case it is not safe for the scraper. So, this is the best way dump before turning, in some cases depending upon your project site you can see that it will turn, before dumping. So, it will turn before dumping that means it is turning in the loaded condition.

This is relatively unsafe for the scraper, sometimes you can see that your scraper will do the turning and the dumping together. So, that will actually increase the dumping time. So, there are different ways to do which way you are going to dump it depends upon your actual project space constraint. Sometimes we have to even go for the third option dumping and turning together, it depends upon the space availability.

So, but the best thing the safe way is you dump the material and then make a turn that is really safe for the scraper then about the turn time of the scraper. So, you can see that the turn time is basically not affected by the type or the size of the scraper. So, hope you remember the picture which I have shown to show the production cycle of the scraper, you can see the scraper commonly you can see that 2 turnings are done by the scraper.

One is the turning in the fill area and other one is turning in the cut area. So, basically when the scraper makes a turn in the cut area the turn time is a little bit higher when compared to turning in the fill area. So, this is because you can see very commonly more congestion in the cut area, more equipment will be involved in the cut area because in the cut area you can see pushers also assisting the scrapers, so many machines have involved in the cut area.

And another thing is your machine has to turn and then spot another pusher to begin the next cycle. So, it has to spot the pusher also. So, all these things will increase the turning time in the cut area when compared to the fill area. So, you can see that average turn time in the cut is 0.31 minute,

but on the fill the average turn time is 0.21 minute. So, slightly the turn time in the cut is greater. So, based on studies people have determined the researchers have determined these values, we can make use of these values for our estimation of the cycle time and the productivity of the scraper.

So, far we have discussed about the cycle time of the scraper. So, we have the 2 different parts of the cycle time, one is fixed and the other one is it variable. So, under fixed we saw the components like you have the loading time, dumping time, turning time, say turning at the fill area, turning at the cut area and you also have the time needed for acceleration, deceleration, braking, all these things makes up the fixed time**.**

The other part is the variable time and the variable time you have your haul onward journey time as well as the return time, that is your return journey. So, all these makes up the cycle time of the scraper. Now let us see how to estimate the cycle time and what all the components of the cycle time of the pusher?

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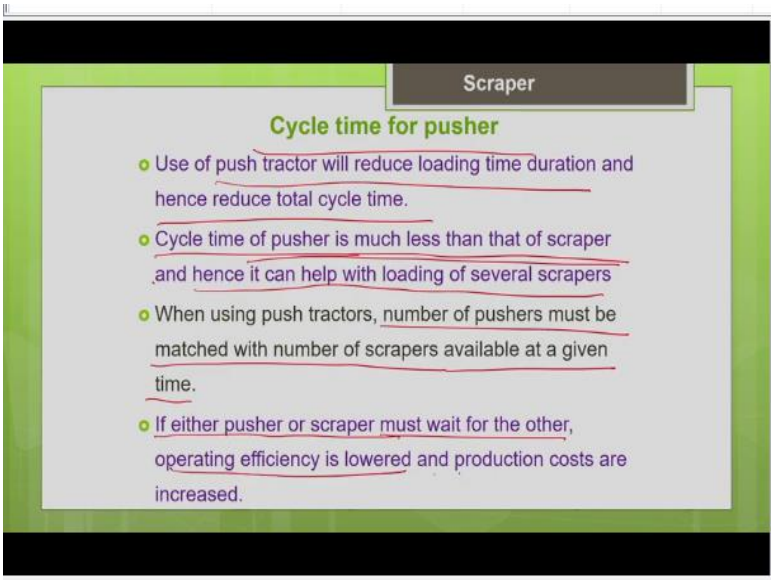

So, as we discussed earlier when you use a pusher for assisting your scraper, you can reduce the loading time of the scraper, it will help you to increase the productivity of the scraper and reducing unit production cost of the scraper. So, use a push tractor will reduce the loading time duration and hence reducing total cycle time and another important thing to be noted is the cycle time of the pusher is much less than that of the scraper.

Because you know that the pusher is helping the scraper only during the loading phase. Once a bowl of the scraper is completely filled then the scraper will get detached from the pusher and the scraper can do the hauling operation on its own after that it will become independent. So, you need the help of the pusher only during the loading phase of the scraper. So, that is why the cycle time of the pusher is much less than that of the scraper and one pusher can serve even up to 4 to 5 scrapers.

So, hence it can help with loading of several scrapers. So, when using push tractors, number of pushers must be matched with the number of scrapers available at a given time. That is very important. So, how many number of scrapers you have and how many number of pushers you have at the project site and we should properly optimize a balanced otherwise what will happen either the scraper has to wait for the pusher or the pusher has to wait for the scraper.

If this happens, it will increase the waiting time and that will increase the cycle time and that will decrease your productivity and increase your production cost. So, that is why we need to balance the number of scrapers and number of pushers, balancing interdependent machines is very important to optimize the production and reduce the cost. So, we are going to discuss that in detail later.

And we will even work out some problems on how to balance the number of scrapers and the pushers? So, this is what is explained here, if either the pusher or the scraper must wait for the other operating efficiencies lowered and the production cost increased. So, that is why we need to balance the number of scrapers and the pushers. Now let us see what makes up the cycle time what all is the components of the cycle time of the pusher? So, as I mentioned earlier the pusher is assisting the scraper during the loading phase.

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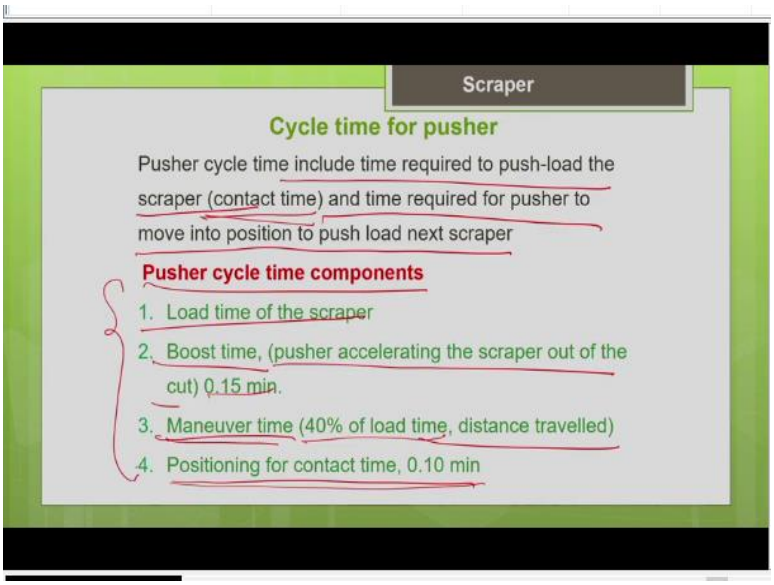

So, that is its contact time with the scraper contact time of the scraper with the pusher. So, after that what happens your pusher will get detached from the scraper and it has to travel and spot another scraper and get ready for pushing the next scraper. So, all these things makes up the cycle time of the pusher. Pusher cycle time includes time required to push load the scraper, that is its contact time with the scraper during its loading phase and apart from that the time required for a pusher to move into position to push load next scraper.

So, depending upon your site, it has to travel and spot the another scraper and get ready to push it. This makes up the pusher cycle time. Let us see in detail what are all the components? One is the loading time of the scraper and the other one is a boost time. The pusher will accelerate the scraper out of the cut. So that is called as a boost time. Pusher accelerating the scraper out of the cut say approximately 0.15 minute can be taken as a boost time, apart from that you have the maneuver time as I told you the pusher has to travel after pushing the first scraper it has to travel and spot the another scraper and get ready for pushing it.

That is a maneuver time. It can be taken as a 40% of load time. That is a distance traveled. There are other things positioning for the contact time. So, contact time with the pusher has to position. So, that it establishes its contact with you the scraper that positioning time is 0.1 minute. All these things makes up the cycle time of the pusher.

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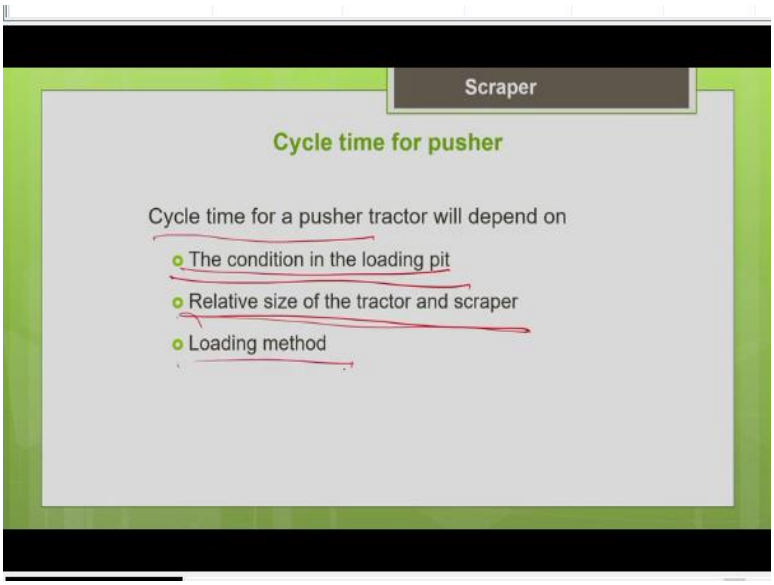

So, this cycle time of the pusher is variable it depends upon various factors, say it depends upon the condition in the loading pit, say if the loading terrain is very hard, consolidated clay. So, in that case, more time is needed for the pusher to assist the scraper. And also it depends upon the congestion at your site. If the site is very congested, it will be difficult for the pusher to spot the scraper. So, it depends upon the condition in the loading pit. And the relative size of the tractor and the scraper is very important.

So, we have to select the pusher size compatible with the size of the scraper. For a bigger scraper, you need to choose a appropriate bigger pusher. So, that you can reduce the cycle time. So, the relative size of the tractor and the scraper also affects the cycle time of the pusher. And another important thing is the loading method. There are different loading methods. We are going to discuss the loading method also one by one.

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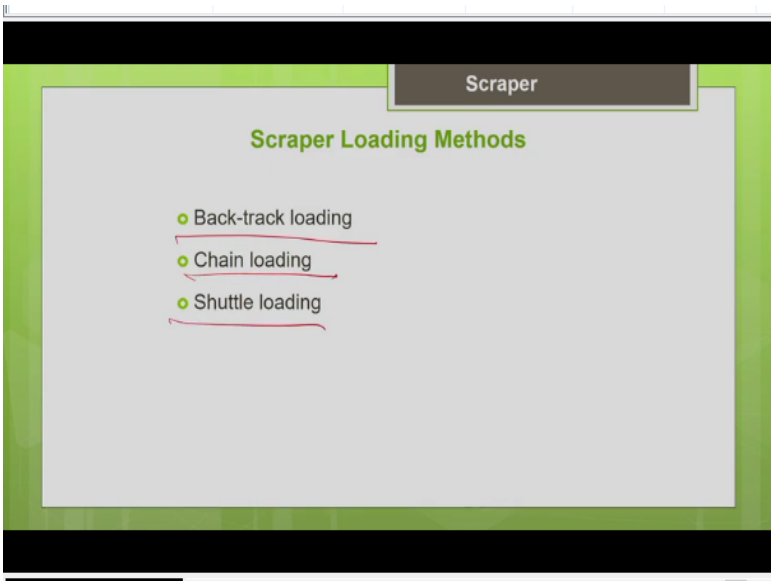

So, let us see what are all the loading methods? Scraper loading methods, back-track loading, chain loading, shuttle loading. So, what are these loading methods we are going to discuss now?

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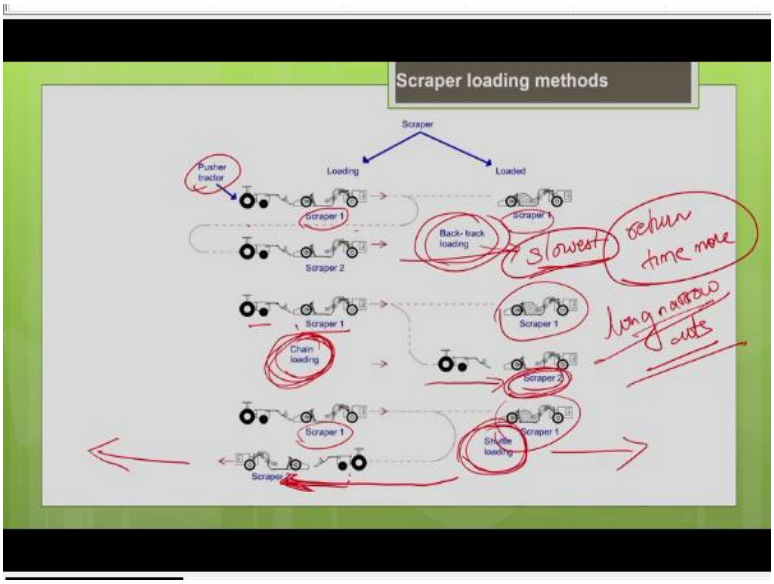

The first is the back-track loading method. So, this pictorial representation will clearly explain the different types of loading methods. So, the first one is a back-track loading, the second one is a chain loading and the third one is shuttle loading. So, what is this backtrack loading? So, the first is the pusher helping the scraper 1, the pusher tractor it is helping the scraper 1 for loading phase for loading. So, once the scraper 1 is completely loaded, your pusher will get detached from the scraper and it will back-track.

So, once the loading of scraper 1 is completed, the pusher will back-track return back and spot the next a scraper, scraper 2 and start pushing it in the same direction. So, that is what is a back-track loading. So, first it is pushing the scraper 1, as a scraper 1 is completely loaded it will start moving on its own. Once the scraper 1 is loaded, your pusher will get detached and return that is backtracking, backtrack and it has to travel some distance and spot the next scraper 2.

And then start pushing again in the same direction, it starts moving again in the same direction. So, that is what is your back-track loading method. So, one limitation of this back-track loading method is it needs additional time for returning back backtracking. So, that is why we call this as a slowest method. So, this is the slowest of all the methods which we are going to discuss now. So, here you can see that the return time is more, return time is more because of the backtracking.

So, everything the actual value will depend upon your project site. So, we cannot tell the exact value but basically your back-track method takes longer time because the pusher has to return back, it has to back-track and spot the next scraper and then start pushing it again in the same direction. But this is more commonly adopted by everyone because the people prefer the cutting in the same direction.

So, that is why they prefer the back-track loading method. And the next method which we are going to discuss is your chain loading method. So, this we commonly follow for long cuts, long narrow cuts like your roads, we can follow the chain loading method, say here your pusher is pushing the scraper 1, once a scraper 1 is completely loaded the scraper 1 is now in fully loaded condition. Now your pusher will get detached from the scraper 1 and the pusher start pushing the next scraper.

But here is what happens the scraper 2 will come and wait near the pusher. Your pusher may not backtrack again; it may not return back again and spot the next scraper. So, the scraper 2 will come and wait near the pusher. So, this is commonly adopted in long roads I mean long narrow cut like roads. So, here also since the returning time is reduced. So, you can say that the chain loading cycle time will be less.

The next one is shuttle loading, this is not commonly followed, but you can follow it when you have 2 fill areas. That means you have a fill area in this direction as well as you have fill area in this direction. If you have fill areas in both the direction, then you can follow the shuttle loading. So, what happens here is the pusher is pushing the scraper 1. The scraper 1 is now completely fully loaded, it is fully loaded.

After that your pusher is getting detached from the scraper 1 and it starts pushing another scraper in the opposite direction. Your pusher is pushing another scraper in the opposite direction that means you have a scraper moving in both directions in this particular site because we have fill areas in both directions. So, in that case it can go for shuttle loading, here also return time is reduced.

So, the cycle time is reduced. So, when you compare all these 3 methods, you can see that your back-track is the slowest method, the cycle time is relatively higher because it has to back-track or return to support the next scraper but your chain and shuttle loading though they are not commonly followed so, but they are having the lesser cycle time and we know the reasons already.

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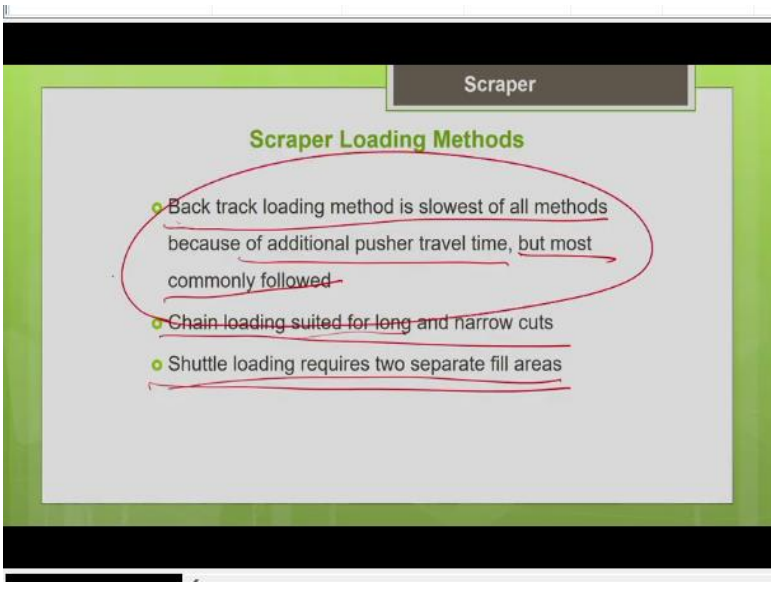

So, to summarize back-track loading method is the slowest of all the methods because of the additional pusher travel time for backtracking on returning. But most commonly followed because people prefer cutting in same direction. Chain loading, it is suited for long and a narrow cut, here

the return time is reduced. Shuttle loading requests 2 separate fill areas in both direction. So, you can see scrapers moving in both directions, this is also having shorter cycle, but this is the one which is commonly followed.

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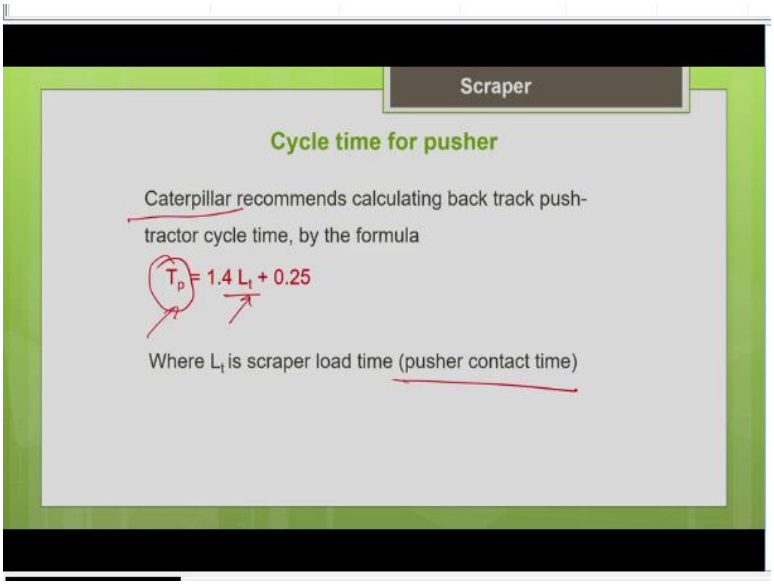

So, there is a thumb rule formula given by the caterpillar to determine the cycle time of the pusher, if you know the loading time of the scraper you can determine the cycle time of the pusher. Tp is the pusher cycle time and Lt is the scraper load time, the contact time of the pusher with your scraper during the loading phase of the scraper. So, if you know the loading time you can calculate the pusher time using this formula.

$$T_p = 1.4L_t + 0.25$$

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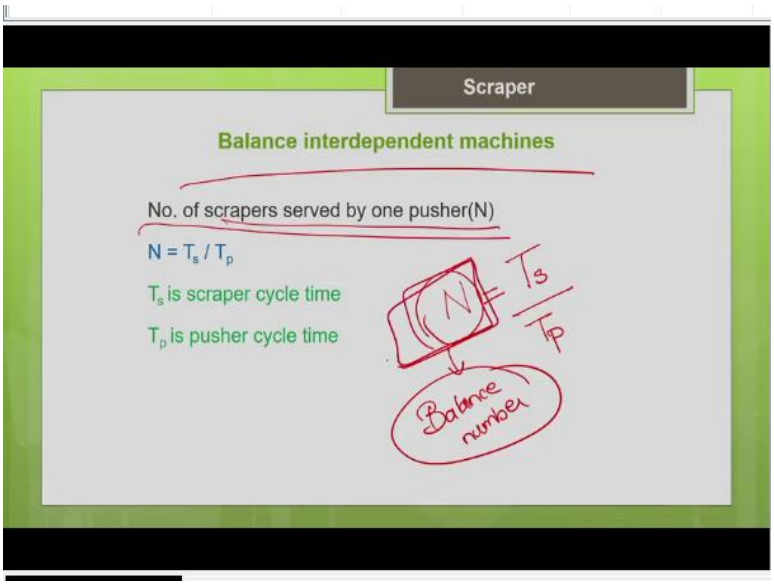

Another important thing as I mentioned earlier, we need to balance the interdependent machines, your scraper and pusher are interdependent machines, they work together. So, we have to balance them, we have to choose the correct number of scrapers and pushers, so that one need not wait for the other. So, we have to reduce the waiting time of the machines, so that we can reduce the cycle time, increase the productivity and reduce the production cost.

So, how to find the number of scrapers which can be served by one pusher? As I told you pusher cycle time is less it is assisting the scraper only during the loading phase of the scraper. So, one pusher can serve even 4 to 5 scrapers. So, now how to determine the number of scrapers served by 1 pusher? So, N is the number of scrapers served by one pusher, it is equal to cycle time of the scraper divided by a cycle time to pusher. This gives you the balanced number. So, this is your number.

$$N = \frac{T_s}{T_p}$$

So, when you choose the balance number of scrapers and pusher you can see that there will be minimum waiting time of scraper and pusher and you can see that when you adopt the balance number the production level of both the machines are same, the production level will be same and the scrapers and the pushers will be working at the maximum production capacity, when you have the balance number of scrapers and the pushers because they are waiting time is less. So, that is why it is always preferable to go for the balance number of the scrapers.

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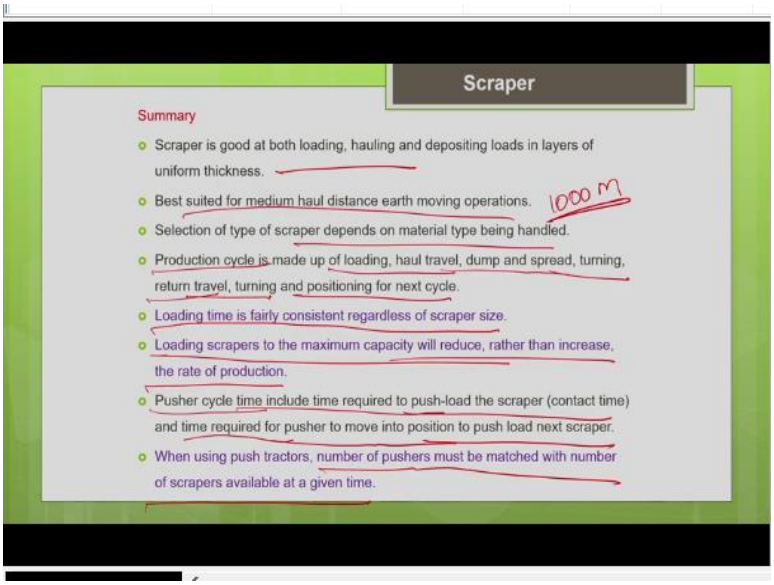

So, now let me summarize whatever we have discussed in this lecture 11. So, we know that the scraper is good at both loading, hauling and it can dump and spread the material in layers of uniform thickness. So, that is advantage that makes it more versatile, it is both good in loading and hauling and it can be used for depositing the material your dumping and spreading can be done in one continuous operation.

So, best suited for distances up to 1000 meter the scraper economical haul distance is up to 1000 meter, so more preferable for the projects like roads and dams. And there are different types of scraper; the selection depends upon the type of material. So, we have even discussed the chart which shows the zone of classification of the type of scraper with respect to the material type. And we know what all the components of the production cycle, it is made up of loading, haul travel, dumping, spreading, turning, return travel, again turning.

So, you have turning in the fill area as well in the cut area and then maneuver positioning for the next cycle. All these things makes up the production cycle of the scraper and we also discuss that loading time is fairly consistent regardless of the scraper size. So, whatever may be the size of the scraper are compatible with that you have to choose the size of the pusher. So, since we choose compatible sizes, the loading time is going to be fairly consistent.

The loading scrapers to maximum capacity will reduce rather than increase rate of production. So, we should not try to load the scraper to the fullest capacity because we saw that as a scraper bowl is almost full, you can see that the incoming material will encounter the resistance from the material which is already lying inside the bowl. So, you can see that unnecessary it will result in increase in your loading time.

So, do not try to load scraper bowl to its fullest capacity, find the optimal loading time from the load growth curve which you can get it from the equipment manufacturer and you have to follow the that particular optimal loading time. Then the pusher cycle time includes the time needed for push loading the scraper so you are going to push load the scraper as well as the time needed for moving the pusher into position to push load the next scraper, all these things makes up the cycle time of the pusher.

And when you are using the push tractors, we have to balance the number of scrapers and the pusher, number of pushers must be matched with the number of scrapers. So, that we can minimize the waiting time of the scraper and the pusher.

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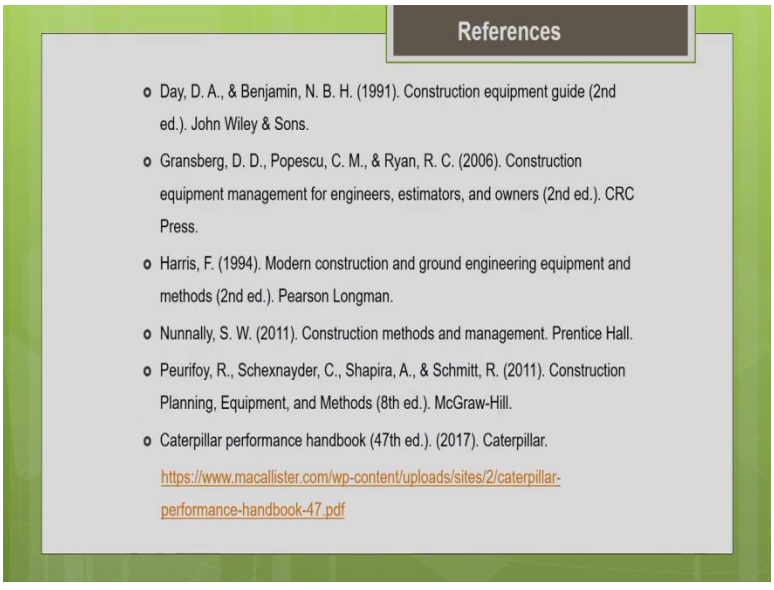

So, these are the textbooks which I have referred for this part of the lecture. So, in the next lecture, we will be working on some illustrations on how to estimate the productivity of the scraper and also we will work out some problems and how to balance the interdependent machines like scraper

and the pusher, how to decide number of scrapers and the number of pushes for a particular project, so that we can reduce the waiting time of the machines. Thank you.