Construction Methods and Equipment Management
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Lecture-9
Engineering Fundamentals of Moving Earth

Hello everyone, I welcome you all to the lecture 9 of this course construction methods and equipment management. In this lecture we are going to discuss about the fundamental of earthmoving operations. So, what are all the different fundamental terms related to earthmoving operations and we will be exposed to in this particular lecture.

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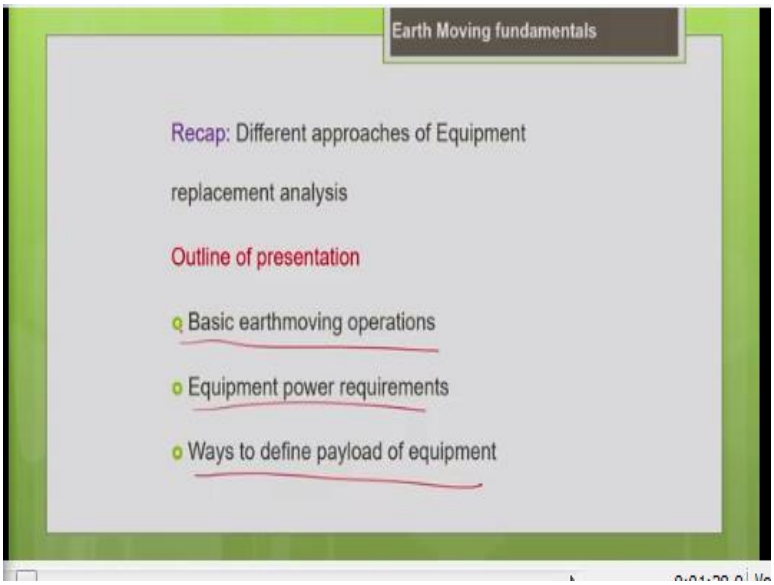

And the let us have a recap of what we learnt in the last lecture. In the lecture 8, we have discussed about the different approaches of the equipment replacement analysis. So, let us look into the outline of today's presentation. In today's presentation I will introduce to you the basic earthmoving operations. So, what are all the basic earthmoving operations and followed by the discussion on what are all the power requirements of the equipment for a particular project condition.

What are all the power requirements, how to estimate the required power? So, these things we will be discussing. And we will also see what are the different ways to define the payload of particular equipment, say how to express it volumetrically or gravimetrically. So, what are the different ways to express the payload on what volumetric basis. So, we are going to learn in this particular lecture.

Basically, this particular lecture is to introduce to you the fundamental terms related to the earthmoving operation. Because followed by this particular lecture, we will be discussing on different earthmoving equipments and the productivity estimation of the earthmoving equipments. So, this particular lecture will help you to understand some fundamental terms related to the earthmoving operation, so that you can have a better understanding of the equipment.

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So, what is the need of earthmoving? So, basically this earthmoving is a very, very broad spectrum. It refers to a broad spectrum of construction activities, it may be simple levelling of ground or a grading of ground or just stripping of the top soil, or it may be some deep excavation for the purpose of making the foundation or excavating trenches for pipeline and or it may be embankment construction. So, all these things involve the earthmoving operation. So, you can see that this earthmoving is a very common activity which can be seen in the most of the construction projects.

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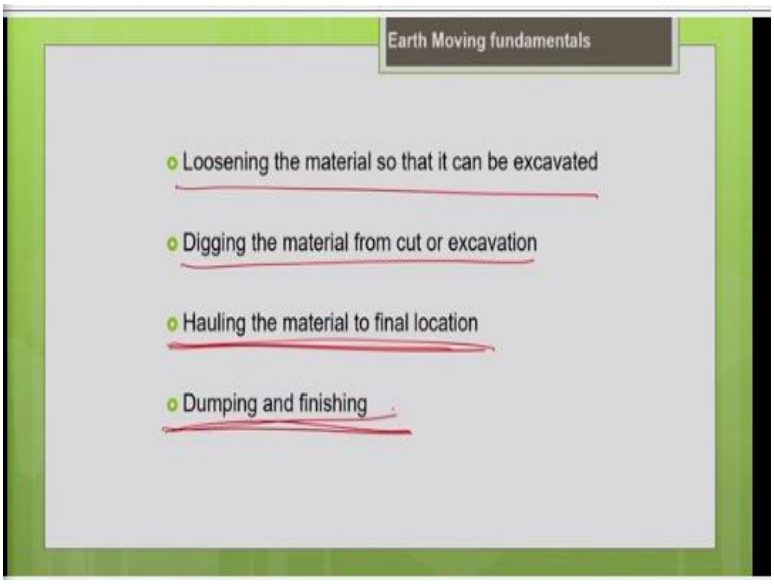

Now let us see what are all the basic steps in the earthmoving operation? To start with we have to first loosen the material which we are trying to move. So, loosening the; material, so that it can be excavated. So, if you loosen it before digging it, it will be more easier to dig, so it will enhance the productivity of the job. So, the first step is loosen the material you can use a tractor with the reaper and then loosen the earth followed by digging the material from the cut of the excavation.

So, after digging, you are going to haul the material to the location where you need to dump it. So, how much distance you need to haul, that depends upon your project requirement. Say for example, for dam construction or for a highway construction, the haul distance maybe longer. So, depending upon your dumping site, depending upon your project requirement the haul distance will vary.

The last step is dumping and finishing. So, you have to dump the hauled earth. So, in some cases, we just dump it in a haphazard manner, so because you may not use that particular material again. So, on organized manner you can just dump it or if you are going to use a dumped material as a fill material, then you have to dump it in an organized manner or uniformly spread it then compacted with the rollers to the required thickness.

So, depends how we are going to dump, depends upon your project requirement. So, these are basic operations involved in most of the earthmoving projects.

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So, let us look into what all are the earthmoving equipment which are commonly used for the earthmoving operations. So, you can see this bulldozer, this is a scraper, this is the loader, front end loader and this is a backhoe, we call this an excavator. So, basically which equipment we need to select depends upon your project requirements. We have discussed about the factors influencing the selection of the equipment in the lecture 1, hope you remember.

So, let us try to have a small recap of what we discussed with from earthmoving perspective. So, basically for the earthmoving operation which equipment I need to select. First you need to think about the haul distance needed. So, what is the haul distance needed for a project because every equipment has it is own economic haul distance. Say for example, bulldozer, it has economic haul distance of 100 meter.

Scraper, you can have economic haul distance of up to 1000 meter. Here loader if it is wheel mounted, you can even go up to 200 meters, this one you cannot go beyond 20 meters. So, it is mobility is very much limited, the backhoe. So, depending upon your haul distance requirement, you have to make the choice. So, another important thing is your project requirement.

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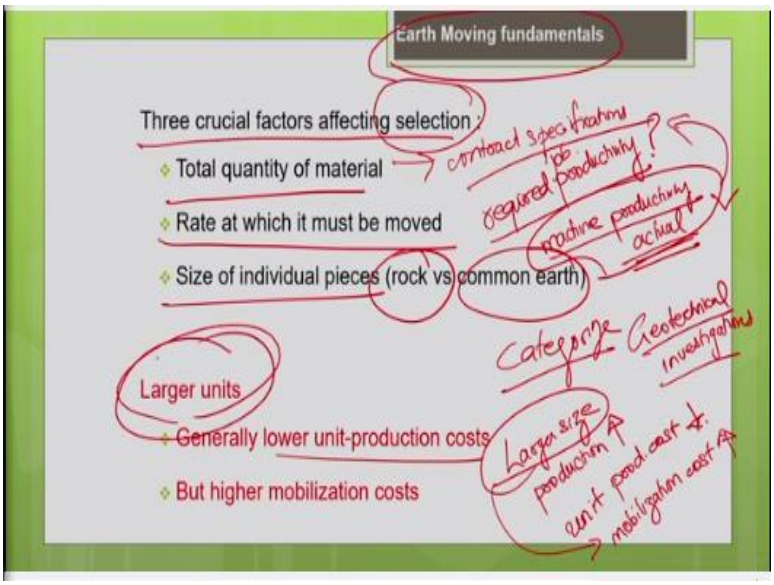

So, basically what are the project requirements, you need to know what is the quantity of material to be excavated? So, that I can know it, from your contract specifications and the drawings, so I can get to know what is the total quantity of material which has to be excavated? And how much is a duration allocated for this particular activity. So, that also you can get it from the specifications from the project schedule or the work breakdown schedule, you can get the duration allocated for the particular activity.

So, now you know what is the; required productivity for that particular job. So, from the contract specifications you can get to know what is the required productivity? So, from the equipment manufacturer, you can know what is the machine capability or the machine actual productivity. So, you can get to know from the manufacturer then you can make the selection accordingly. You know what is the required productivity for that particular job and what is the machine actual productivity you can get it from the manufacturer, so, based upon that you have to make the selection.

So, 3 crucial factors which affect a equipment selection are the total quantity of the material to be moved and the rate at which it must be moved, that you need to know from the contract specifications. And another important thing with respect to earthmoving operation is you need to categorize the material. You need to categorize what type of material you are going to handle. Because the equipment you need to handle common earth and the equipment you need to handle

the rock, they are totally different. So, if you need to excavate the rock, you need to go for different method, drilling, blasting. If it is a weaker rock you can go for a ripper.

So, it depends upon what material you are going to handle, whether it is a common earth or consolidated clay. So, depending upon the size of the individual pieces, you have to make the selection of the equipment. Basically you need to do some geotechnical test or the investigations to categorize the material or you maybe even supply with the information by the contractor.

Or you may have to carry out some tests to know what is the type of material which are going to handle, according to that you have to make the selection. So, basically your economic haul distance of the particular machine, what is the haul distance needed at the project site? What is the underfoot conditions in your project? That will decide the mounting of your machine. And what is the required productivity of your project? And what is the actual productivity of your machine?

All these things you need to know before selecting the earthmoving machine. Another important thing you need to have in mind is, if you go for a larger units, larger equipment, you will have a better reduction in the unit production cost. Because you know that bigger the size of the machine, it is production will be more. So, larger the size of the machine it is production is going to be higher; the volume of production is going to be higher. So, the unit production cost will also be lower**.**

But one thing you have to keep in mind is when you go for larger size machines; your mobilization cost will increase, that you should always keep in mind. Mobilization cost, of mobilizing the machine to the particular project site that will increase when you go for larger size machines. So, you have to achieve a trade off and you have to work out the economics and then justify the selection of your machine.

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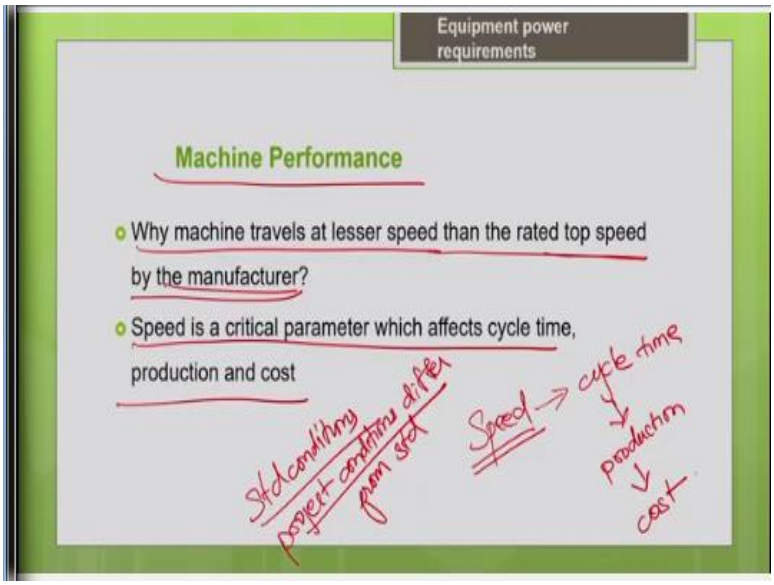
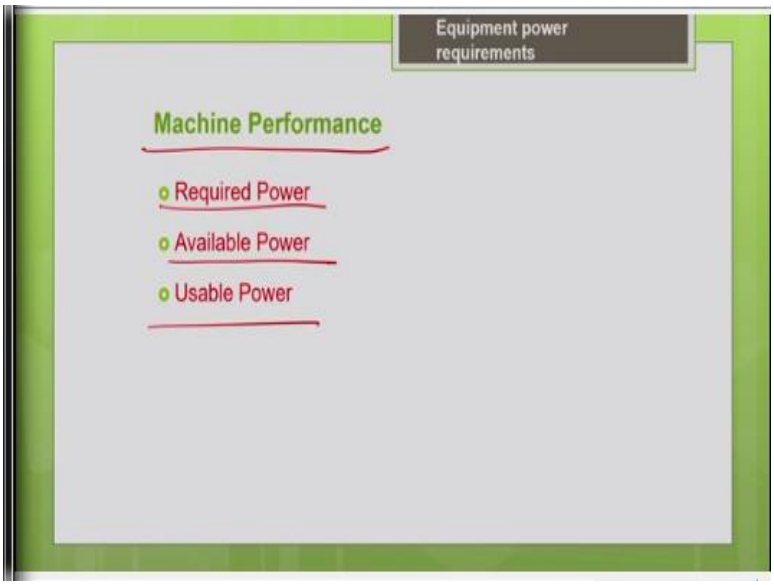


So, there are some more important terms you need to learn with respect to the machine performance. Basically, speed is a very important parameter used to quantify the machine performance. Most of the contractors are interested in the speed of the particular equipment. Because speed will affect your cycle time of the machine that is going to affect your production of the machine, that is going to in turn affect the cost associated with the machine.

So, speed is a critical parameter which affects the cycle time production and the cost. That is why we are very much interested in the speed of construction equipment. So, there is one common question always, why the machine travels at a lesser speed than the rated top speed by the manufacturer. So, most of the times we see that the manufacturer speed rating will be different. But what we realize in your project site will be lesser than the manufacturer rated maximum speed, why is it?

It is because the machine speed rating by the manufacturer is done under some standard conditions, but your project conditions may differ from the standard conditions. So, that is the reason we are not able to realize in many cases the maximum speed or the maximum efficiency prescribed by the manufacturer. So, that is why we need to know what is the expected performance of this particular machine for your project condition, you should be able to analyze that. So, we are going to learn how to analyze the particular performance in the upcoming slides. **(Refer Slide Time: 10:33)**



So, there were some important terminologies, which you need to learn related to machine performance. So, required power, available power, usable power, so these are the 3 important terms related to power requirements of the machine, we are going to learn what are these terms one by one in the upcoming slides.

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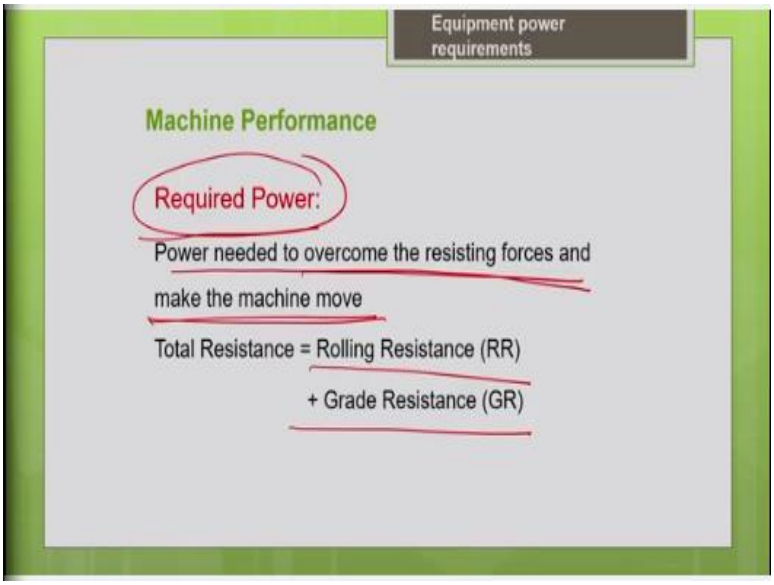

So, what is this required power? So, generally, what is the power needed by the machine to overcome the resisting forces in the project site and keep the machine moving, that is what is a required power. So, you know that every project site is unique, the underfoot conditions of the project site differs from site to site. So, the equipment which are going to use in a particular construction project site has to overcome all the resisting forces in the particular project site.

And then it should keep the machine moving. So, you should select the machine with the sufficient power, so that it can overcome the resisting forces in the underfoot conditions. So, that is what we are going to see, how to determine the required power of this particular machine? So, it is basically the power needed to overcome the resisting forces at the project site and make the machine move**.**

So, what are all the different types of resistances the machine is going to encounter? That is what we are going to see, one is rolling resistance, other one is a grade resistance. We will see what are these rolling resistance and grade resistance one by one in the upcoming slides.

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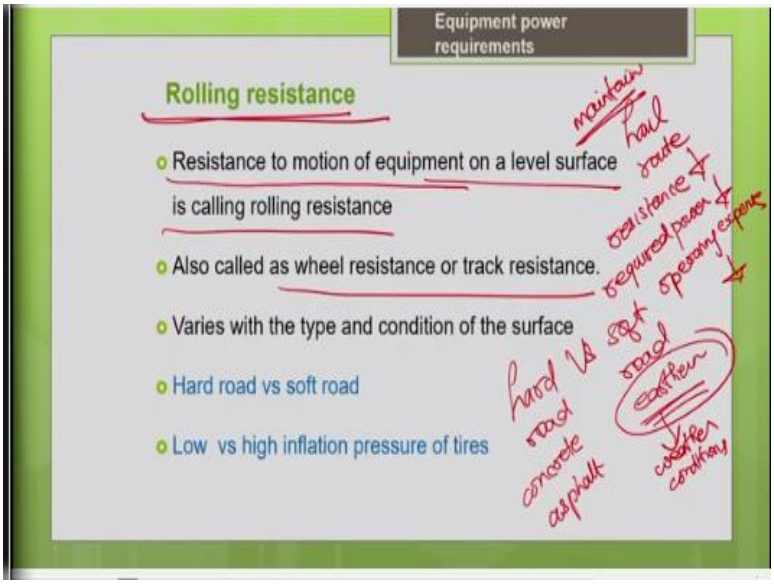

The first thing we will discuss about the rolling resistance. Rolling resistance is nothing but what is the resistance offered by the hauled route to the wheel which is rolling over the particular surface. So, what is the resistance offered by the hauled route to the wheel which is rolling over the particular surface, so that is what is your rolling resistance. So, resistance to the motion of equipment on a level surface is called as rolling resistance.

So, what is the resistance encountered by the wheel, when it is moving on a particular hauled route. That depends upon the type of the hauled route; it may be different for different haul route surfaces. Say for example, for a concrete road the rolling resistance maybe different, for an asphalt road, it

may be different, for the earthen roads it may be different. So, similarly for different types of haul routes the rolling resistances are different.

Basically, we can compare the rolling resistance between hard road and a soft road. So, hard road, you can say a concrete road, your asphalt all these are examples of hard road, your earthen roads are soft road. So, earthen roads, it varies a lot, it depends upon how you maintain it and prepare the earthen roads. If you are properly compacting the earthen roads maintaining the optimum moisture content in the earthen roads, it can even give you a better performance equivalent to hard roads.

So, and this will vary a lot depending upon the weather conditions. So, depending upon what type of drainage you are provided for the earthen roads, so according to that the rolling resistance of the earthen roads will vary a lot with respect to weather conditions and with respect to your maintenance. So, that is why we need to maintain the hauled route, we should spend lot of efforts to maintain the hauled route.

Because if you maintain your hauled route, the resistance encountered by your machine will be less. If the resistance is less, your required power to overcome the resistance will be less, if the required power is less your operating expense will be less. That is why it is always economical to maintain the hauled route**.** So, if you maintain the hauled route well, your resistances encountered by your machine will be less.

So, the required power to overcome this resistance and keep the machine moving will be less and so associated operating expenses and the cost associated with the machine will be less. So, basically this rolling resistance you can even call it as wheel resistance or track resistance depending upon what type of mounting your machine is going to have. So, it maybe a wheel mounted machine or it can be a crawler or track-mounted machine. So, according to this you can call it as wheel resistance or track resistance.

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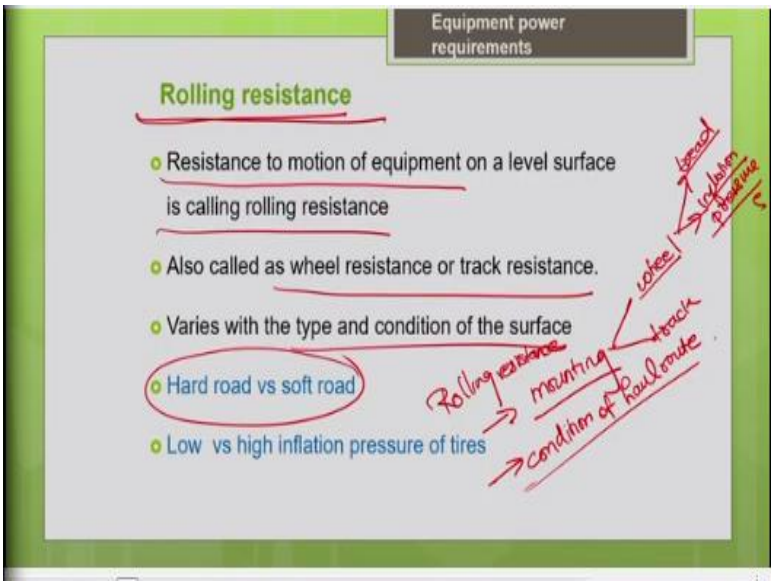

As I told you, it varies a lot with the type and the condition of the surface. And also, it depends upon the mountin, it depends upon the condition of your surface, condition of your hauled route. So, mounting in the sense, it can be either a wheel mounted or it can be a track mounted. If it is wheel mounted, even your dimension of your tyre, the tread dimension of your tyre and the inflation pressure of your tyre, all these things are going to affect your rolling resistance.

Your rolling resistance is going to depend upon so many factors; one is on your mounting. If it is going to be a wheel mounting, it depends upon the dimension of your tread, it depends upon inflation pressure in your tyre. Apart from that, it also depends upon your condition of the surface on which the wheel is moving. So, we were comparing the rolling resistance of the hard road and the soft road. So, I gave you the examples for hard road this soft road. So, your concrete and asphalt roads are hard roads and earthen roads, you can take it as an example for this soft road.

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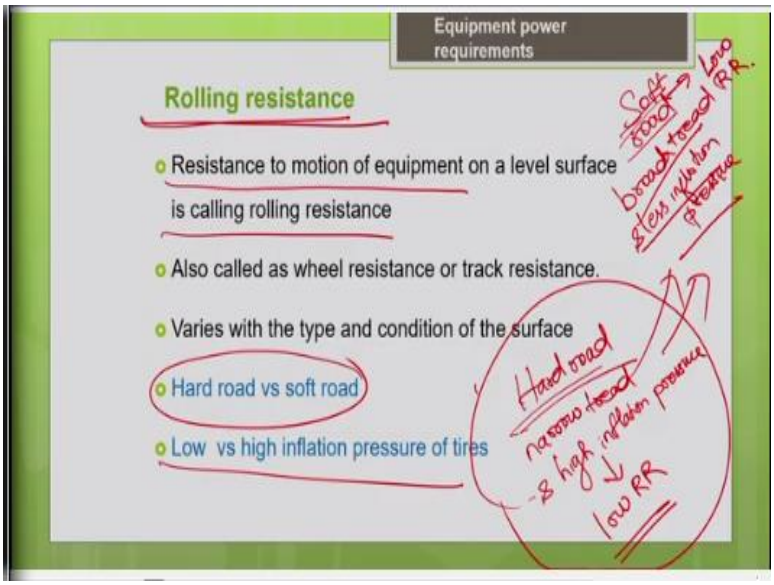

Say in a hard road, if you consider the rolling resistance, your wheel with a narrow tread, say a wheel with a smaller dimension that this narrow tread and high inflation pressure in the tyre, so that will give you low rolling resistance. So, if you see in the hard road to have a low resistance I need tyre with narrow tread smaller dimension and high inflation pressure. So, that the contact area of the surface will be the minimum, so that the resistance will be minimum, so this is for the hard road, but the same thing will not apply for the soft road.

If you look into the soft road, that is an earthen road. In the earthen road, if you go for narrow tread and high inflation pressure in the earthen road or the soft road, what will happen? The tyre will sink into the road, so it can easily sink into the road if it has high inflation pressure and narrow tread. Because generally in the softer surfaces the tyre tends to sink, it seems to a depth till it attains a contact area, so that the load can be distributed.

So, till it reaches a particular depth it will sink till it attains a particular contact area. So, that is why in the soft road, you should have a broader tread. Broader tread I mean, wider tires and you should go for less inflation pressure. So, this will give you low rolling resistance in the soft road. So, the things which are favourable for the hard road are not favourable for the soft road, so you should note that**.**

For the soft road, I need a tyre with a broader contact area, so that it will not sink much into the softer road. And also I need a tyre with lesser inflation pressure, so that it will not sink much into the softer road. So, accordingly you have to make the selection of your mounting, so that you can have a lesser rolling resistance. So, now we have discussed what are all the factors which affect the rolling resistance?

Basically, you have to maintain a hauled route, so that the rolling resistance is minimum, so that your amount of power needed by the machine to overcome the rolling resistance will be less that will make it more economical.

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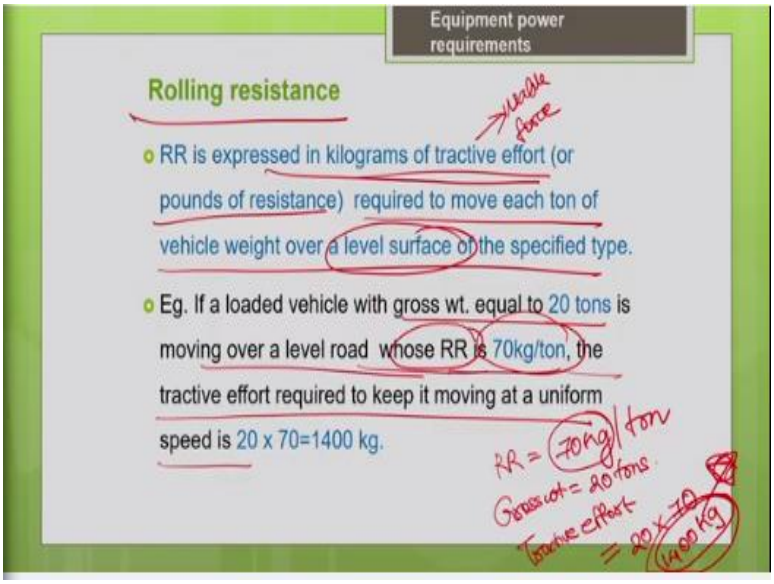

So, this rolling resistance is expressed in kilograms of tractive effort. So, tractive effort is nothing but your usable force, usable force at the point of contact between your wheel and the ground. So, rolling resistance is expressed in kilograms of tractive effort or pounds of resistance, these are just different types of units. So, either you can express it in kilograms of tractive efforts or pounds of resistance required to move each ton of the vehicle weight over a level surface of the specified type.

So, basically it is the amount of force needed to move unit weight of the machine on a level surface, why we consider level surface? Because the effect of grade, on the effect of slope will be considered separately under grade resistance, that we are not considering here under rolling

resistance. So, basically, rolling resistance you can see that it is expressed in kg of your tractive effort needed to move a unit weight of your machine over the particular surface.

Say for example, you have a loaded vehicle, it is gross weight is equal to 20 tons, it is moving over a level road. So, whose rolling resistance is given as 70 kg per ton. So, this rolling resistance value, you can get it from the literature for different types of haul routes, earthen roads, properly maintained earthen roads, poorly maintained earthen roads, for concrete roads, for asphalt roads for different types of roads, for different types of mounting of machines.

If it is rubber tyre mounted, for different inflation pressures, what is the rolling resistance value? You can get it from the literature. So, I have given you directly here for this particular problem. Say the rolling resistance for this haul route is given as 70 kg per ton, that means you need 70 kg of force, 70 kg of tractive efforts to move unit ton of your machine. Now you need to find what is that tractive effort required to, keep it moving at a uniform speed.

So, for this particular road, the rolling resistance is given as 70 kg per ton. That means, to move a unique kind of machine on the particular surface, I need 70 kg of force. Now you know what is the gross weight of your machine? What is the gross weight of your machine? It is nothing but 20 tons. Now we can calculate what is the tractive effort needed to overcome this rolling resistance and keep the machine moving. So, what is the tractive effort needed?

Let us multiply this weight of the machine 20 times into 70 kg that gives you 1400 kg. So, this is a tractive effort needed to move the machine over this particular surface. So, why do we calculate all these things? So, that you can make a selection of a machine accordingly. So, the required power to overcome this resistance is 1400 kg. So, you have to make a selection of the machine accordingly, so that this much amount of power is available with a particular machine to overcome this resistance in this project site.

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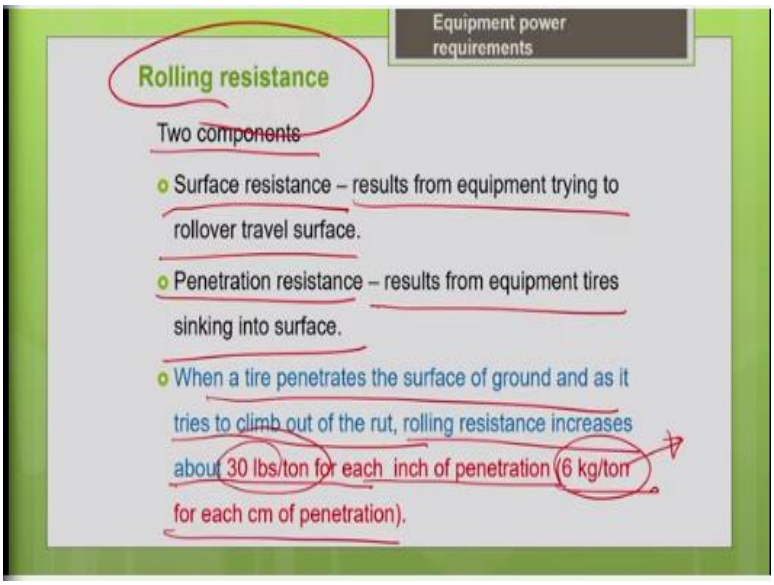

So, what are all the 2 important components of the rolling resistance? Let us see, one is the surface resistance other one is your penetration resistance. So, you can break this rolling resistance into 2 components, one is at the surface. So, the resistance which is encountered at the surface when the; wheel is moving over or rolling over the surface that is surface resistance.

Penetration resistance is nothing but the resistance encountered when the tire is sinking into the surface that is your penetration surface, this will happen for soft roads. Surface resistance results from the equipment trying to roll over the travel surface. Penetration resistance results from the equipment tires sinking into the surface. So, both these things we have to estimate and add it to find the total rolling resistance.

Now let us see how to estimate the penetration resistance. Say when a tire penetrates into a surface, so the resistance, the rolling resistance increases. So, say for example when the tire is sinking into the particular surface, you need some additional efforts to come out of the particular rut and keeps the machine moving. So, you need some additional efforts to bring the machine out of that rut and keep it moving.

So, what is the additional effort? That is what we are going to find now. So, when a tire penetrates into the surface of the ground and as it tries to climb out of the rut, the rolling resistance increases

about 30 pounds per ton for each inch of penetration. So, for 1 inch of penetration into the surface, how much efforts we need? 30 pounds per unit weight of the machine.

In SI units you need 6 kg per ton, 6 kg per unit weight of the machine, for each centimeter of penetration of the tyre into the surface. So, basically your rolling resistance increases by 6 kg per ton for each centimeter of penetration of the tyre into the surface. So, using this you can calculate your penetration resistance.

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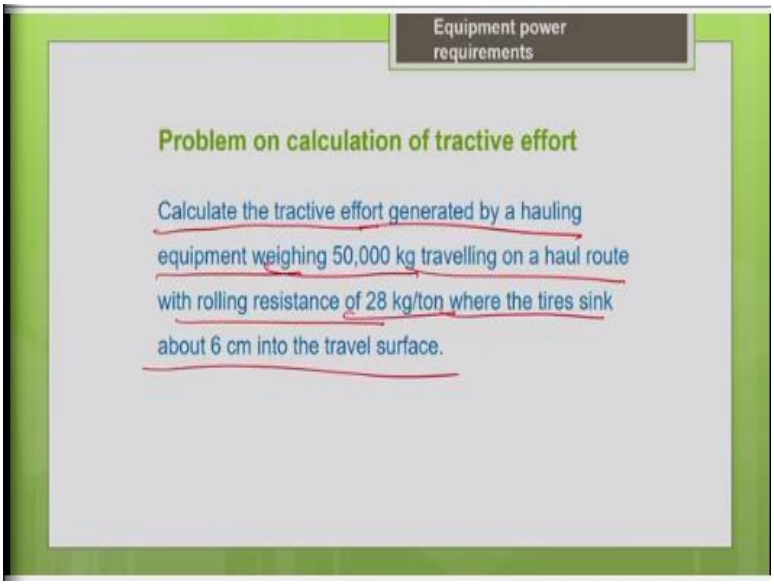

Now, for better understanding, let us work out a problem on calculation of the tractive effort. So, calculate the tractive effort generated by a hauling equipment, it is gross weight is given as 50,000 kg, it is traveling on a haul route. It is rolling resistance is given to you directly you can take it from the literature for that particular haul route; it is given as 28 kg per ton. And another important thing to be noted is your tire is sinking about 6 centimeters into the travel surface.

That means you have to take into account the penetration resistance also. Now we are going to find what is the total tractive effort needed to overcome this resistance is in the underfoot conditions in your project site.

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