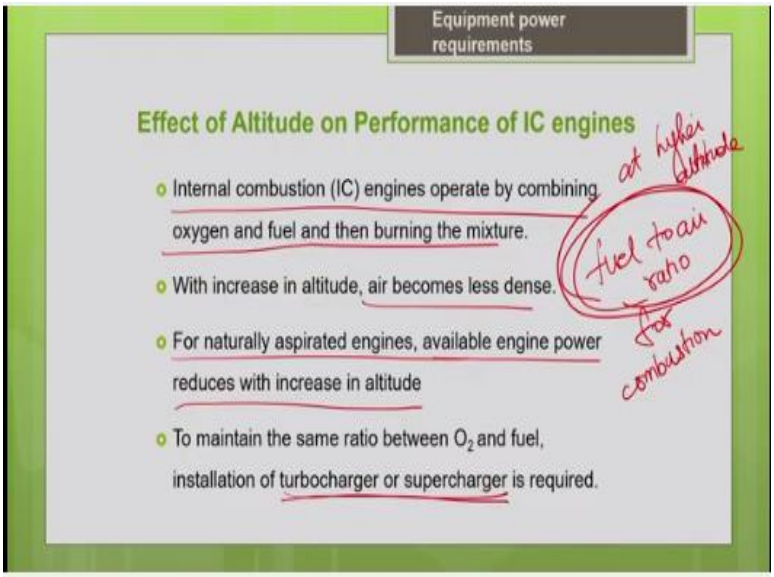

Now let us see what is the effect of altitude on the performance of the engine? So, as we discussed earlier, the usable power depends upon the underfoot conditions, altitude and temperature. So, you know that the horsepower rating of the machine is done with the standard conditions by the manufacturer. So, they might have done the horsepower rating at standard temperature and the standard atmospheric pressure.

So, if your project site is going to have a temperature or the atmospheric pressure different from the standard conditions, then obviously the efficiency of the machine is going to be different. So, what is the effect of altitude on the performance of the internal combustion-based engines? We are going to see now. So, generally most of the construction equipments, what we are using at the project site or IC engines or internal combustion-based engines.

So, for the combustion mechanism, the fuel air ratio is very important. So, you know that as the altitude increases, so if your project site is located at a higher altitude. In that case you can see that the atmospheric pressure will be lesser, your density of air will be less. So, if you are not able to maintain the fuel to air issue, then the combustion process will not be efficient.

In that case in your project site, if the altitude is going to be higher the efficiency of the machine will be affected. So, we have to take into account how much the efficiency is going to be affected? So, basically the internal combustion engines you know that they operate by combining oxygen

and fuel in and then burning the mixture. So, that is why I told you, you have to maintain the fuel to air ratio is very important for the combustion process.

So, with increasing the altitude, your atmospheric pressure will reduce so your air is becoming less dense, so this ratio gets affected. So, that is why your efficiency of the machine will get affected. So, the efficiency what we realized with the machine at the new sea level will be higher. The same efficiency we cannot realize in a project set at a higher altitude, so that we should understand.

So, for naturally aspirated engines the available engine power reduces with increase in altitude that is why to compensate the loss in efficiency you should go for some special attachments like your turbochargers or supercharges. There are certain devices which I discussed even in the first lecture. So, these devices will help you to maintain the fuel to air ratio even at higher altitude. So, even at higher altitude you can maintain the fuel to air ratio using this particular turbocharger or supercharger.

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So, I have shown you this picture in the lecture 1, hope you remember, like you can see this blue color indicates the air movement, there will be a compressor arrangement, which will compress the air and supply the air and maintain the air to fuel ratio in the chamber. So, that is how the combustion process is not effective, if you provide this the turbocharger. So, at higher elevations either you should go for these kinds of special turbochargers.

Or you should go for more number of machines to compensate the loss in efficiency or should go for a bigger equipment to compensate for the loss in efficiency. So, you should know that with the increase in altitude your efficiency is going to be affected and you have to take care. So, now we understood that the altitude will affect the usable power available.

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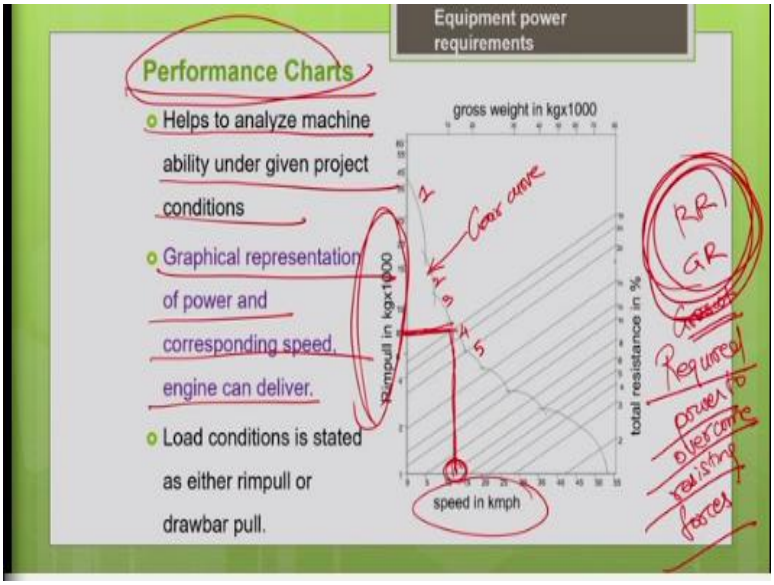

So far, we discussed on what are all the factors the usable power depends of? The usable power depends upon the underfoot conditions, that means the resisting forces in your project site, your altitude as well as the temperature, everything is going to affect your usable power. Now let us see what is the significance of this performance charts? So, generally the equipment manufacturer they supply the performance charts for the models which are manufactured by them.

So, in an equipment handbook, you can see the performance charts of various models manufactured by the manufacturer. So, with the help of the performance chart, we can know what is the actual performance of the machine in a particular project condition? So, that is what is the significance of this chart, it helps you to analyze what is the performance of a particular machine in a particular project condition.

So, it helps to analyze the machine ability under the given project condition, it is basically a graphical representation of power and the corresponding speed an engine can deliver. So, this is a

sample of your performance chart. So, you can see that you have speed in the x axis and in the rimpull in the y axis. Using this performance chart, you can find what is the actual performance of machines in terms of speed for the given project condition.

Say for your project site, you know what is your rolling resistance and penetration resistance? So, penetration resistance you may be, knowing what is the grade resistance for the particular haul route. So, you know the gross weight of the machine, so with that you can find what is the required power? So, what is the required power to overcome the resistance forces, you can know. To overcome the resistance forces in your project site, that you can calculate**.**

For your haul route, if you know what is your rolling resistance and the grade resistance you can. And if you know the gross weight of your machine, you can calculate. So, you can calculate the required power or the rimpull. So, once you calculate that, say for example, if this is going to be say 8000 kg, 8 into 1000 8000 kg. So, you draw a horizontal line intersecting this gear curve, this is nothing but gear curve for different gears, say first gear, second gear, third gear, fourth gear, so different gear curves are there.

Now you draw the horizontal line from the actual rimpull in your project site, so intersecting the gear curve. From that intersection point draw a vertical line, so where the vertical line intersects the horizontal axis that gives you the actual speed possible for this particular project condition, for these particular resisting forces in a project site and the gross weight of a machine.

So, you can find what is the speed possible, what is the machine speed you can realize in your project site that machine performance you can analyzes in this performance chart. So, other way there is also another y axis you can see here. See you can express your resistance in your underfoot conditions using total resistance percentage.

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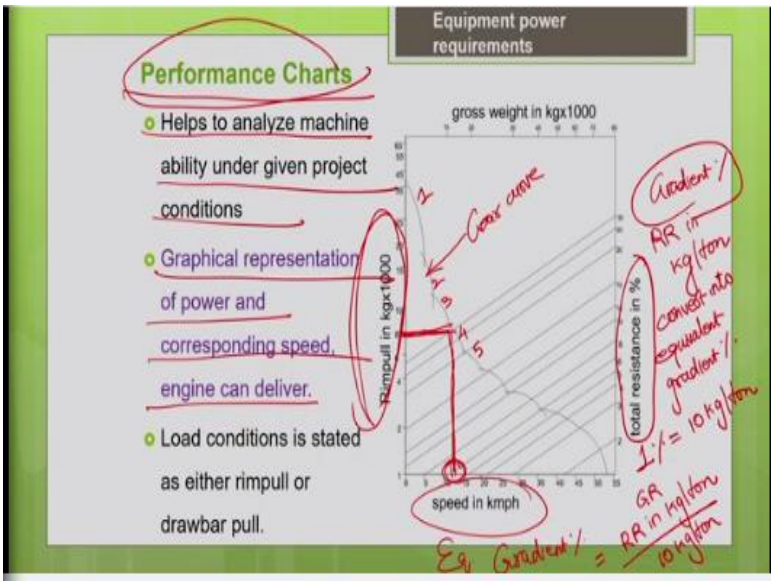

So, already you know the gradient, you know the gradient percent that is the slope percent you know it, the rolling resistance you know in kg per ton. So, this you can convert it into equivalent gradient percent as we discussed earlier. So, you know that 1% is of grade assistance equal to 10 kg per ton, so this we discussed earlier. So, now you can convert your rolling resistance in kg per ton into gradient divides it by 10 kg per ton.

So, this gives you the equivalent gradient percent, so you can get your gradient percent, equivalent gradient. So, you can convert the rolling resistance into equivalent gradient and add it to the actual the gradient percent you will get the total resistance percentage of your project site. So, once you know the total resistance of the haul route in your project site, so you can note that these inclined lines are representing your resistance.

Now you know the gross weight of your machine. So, it depends upon the trip whether it is an onward journey or return journey. In a return journey maybe, your truck maybe in an empty condition, so accordingly you have to note down the weight. In the onward journey it will be in fully loaded accordingly the gross weight will vary. So, note down the actual weight of the machine, so say your weight of the machine is this is your weight of the machine, say your resistance is 8%.

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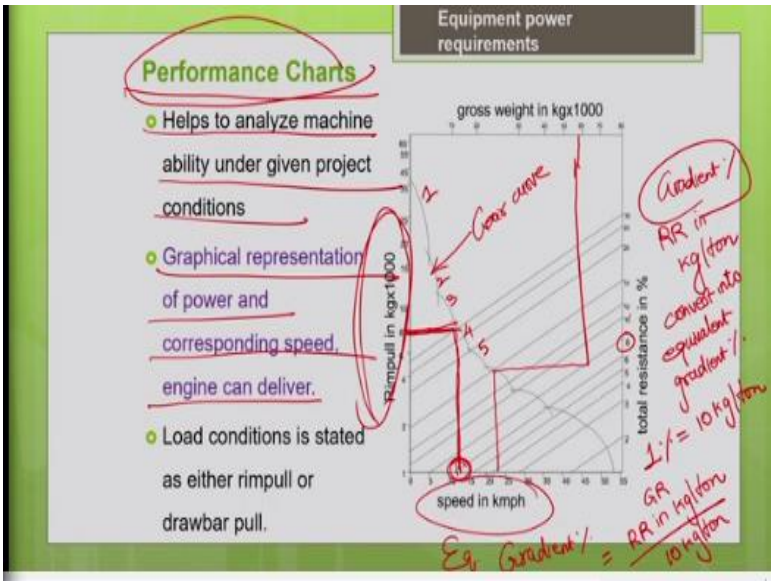

So, you have to draw a vertical line intersecting your total resistance percentage line. Once it intersects your; the total resistance percentage line, then draw a horizontal line to the left intersecting your gear curve. Now drop a vertical line intersecting your speed, so this is how you can find the speed of the machine if you know the total resistance percentage.

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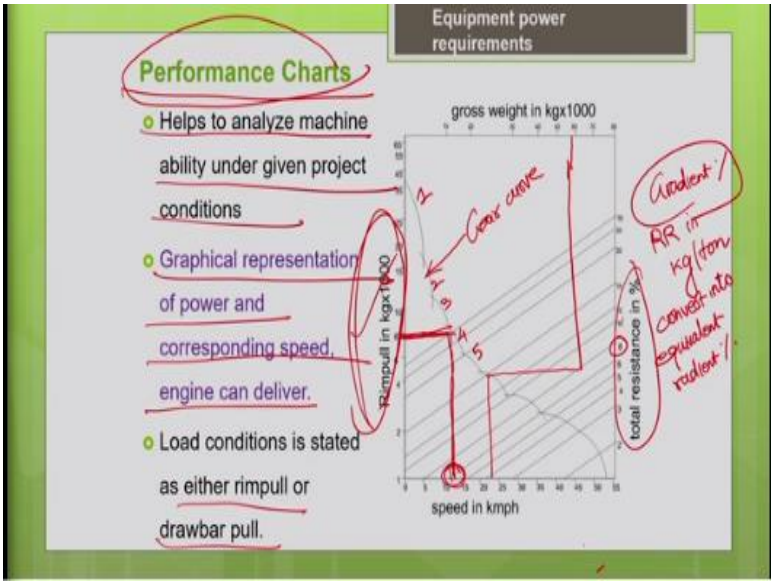

So, either you can use this rimpull in kg and find the speed or you can use the total resistance in percentage and you can use the gross weight and find the actual speed of the machine possible for this particular project condition. So, depending upon the mounting your low condition can be stated either in the rimpull or in the draw pull. So, depending upon the whether it is tyre mounted machine or track mounted machine accordingly.

So, these performance charts are provided by the manufacturer for all the models which are manufactured by them. So, you have to choose the corresponding performance chart and for your particular project conditions you have to find the speed which is possible. So, this data you can use it later in the estimation of the productivity of your machine.

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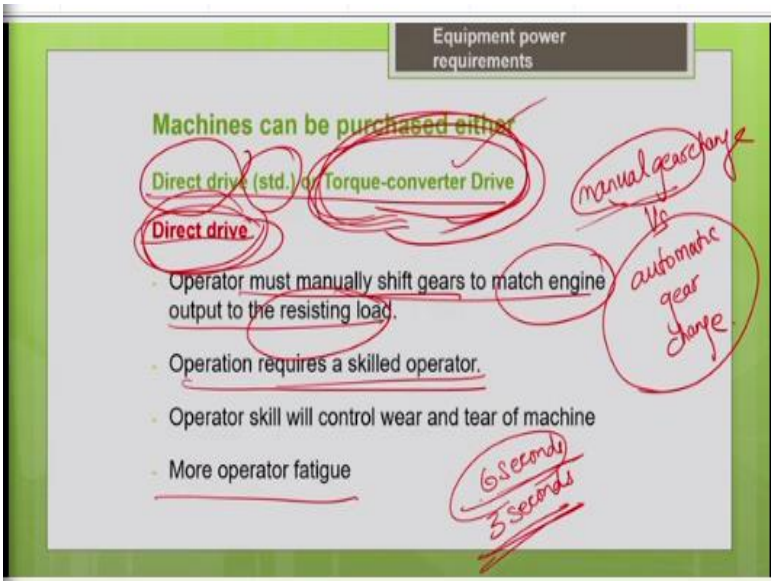

So, another important thing to be noted is the machines when you purchase depending upon the mode of transmission, you can call it as direct drive base machine or torque converted drive-based machine. In a simple way to say it is nothing but your manual gear change versus automatic gear change. So, basically your direct drive is nothing but your manual gear change**.**

A torque-converter drive is called as automatic gear change. So, nowadays if you know that we have a lot of vehicles or cars in the market, with automatic drive option, automatic gear change option. So, the same thing when we are discussing here. So, the technical term which you are supposed to use is for manual gear change which is nothing but direct drive transmission we call it as standard machines.

So, in this direct drive transmission, so the operator has to manually change the gear, he has to manually shift the gear, so according to the load conditions in your haul route. So, you have to manually shift the gears to match the engine output to the resistant load. If the load conditions are

highly variable in the particular case, you can see that it will be really tedious for the operator to change the gear appropriately.

So, if he is a skilled operator, then he can handle it very well. So, this operation requires a skilled operator because he has to manually change the gear according to the load conditions. Particularly for constantly changing load conditions, the operator has to be very skilled, so that he can match the engine output to the resistance load. If there is a mismatch between the engine output to the resisting load, you can see that it will result in wear and tear, it will affect the it will damage your machine.

Your vehicle will come to a stall it will come to a halt if you apply a wrong gear. So, if there is a mismatch between engine outputs to the resisting load or there will be a loss in momentum of your machine. So, this mismatch can affect the life of your machine, it will result in wear and tear of your machine. That is why we need more skilled operator for this direct drive transmission.

So, as I told you operator skill controls the wear and tear and this also results in more operator fatigue, if you look into the cycle time, so if you are going to use an equipment with manual gear change or direct drive transmission, you are supposed to use a technical term, you should say direct drive transmission. So, if you are going to use machines based on direct drive transmission, it will affect the cycle time of a machine.

Because your maneuver time will get affected. Say, for example for manual gear change, if the maneuver time is 6 seconds, for automatic gear change vehicle it maybe lesser it is 3 seconds. So, I am just giving you some examples it may not be the right thing for all the machines, but some approximate numbers I am giving you. So, basically you should know that when you go for this torque converter drive, you can see that the maneuver time is getting reduced, so the cycle time gets reduced.

So, that will affect your productivity and the production cost. So, but your automatic gear changer torque converter drive the initial cost will be more that you should note it, when compared to direct drive transmission the initial cost of torque converter drive will be more. But you can get the

benefits of increase in productivity when you go for this machine. So, when you estimate the productivity of the machine, you should appropriately adjust the influence of the transmission of the machine on the cycle time.

If it is mentioned it is direct drive then accordingly you should know that the cycle time will be slightly more because the maneuver time is more for the direct drive, so extra time is needed for changing the gears, so that time should be taken into account.

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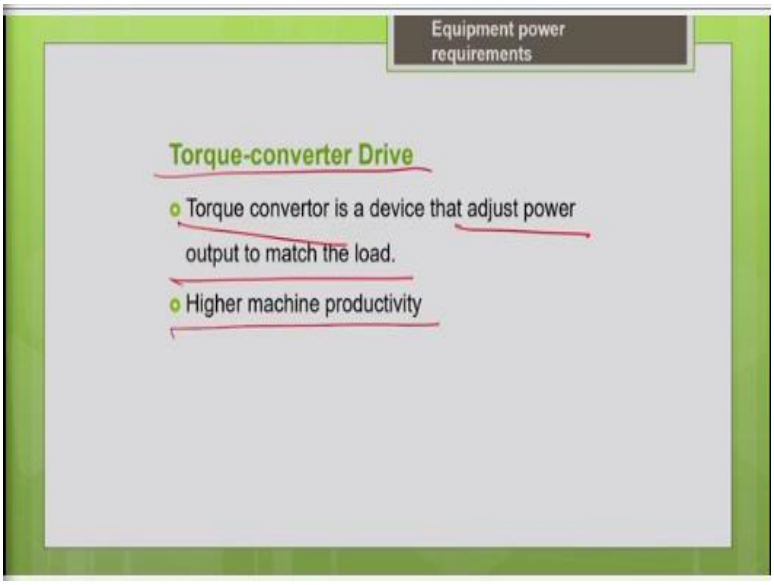

So, other one as we discuss just now is torque converter drive, it is initial cost is high. So, you have a torque converter device here which can automatically match your adjust your power output to match the load conditions, so it results in higher productivity. So, you know why higher productivity because your maneuver time is going to be lesser here, your cycle time will be reduced, so the productivity will increase**.**

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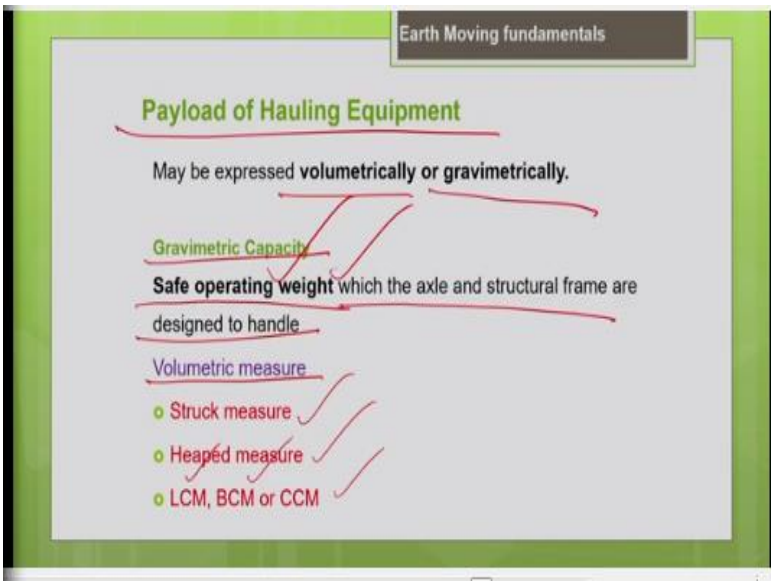

Now let us see what are the different ways to quantify or measure or express the payload of the hauling equipment. You can express the payload either on the weight basis gravimetrically or on volumetric basis. So, basically most of the equipment manufacturers, they give you the data on what is the safe operating weight of the vehicle. So, that is the gravimetric capacity, the safe operating weightness.

That is the weight which the axle and structural frame of the particular vehicle can handle without much wear and tear. So, you have to be very cautious that you should not overload the machine beyond the safe operating weight as prescribed by the manufacturer. So, many circumstances you can see the trucks are often overloaded, they put some sideboards and try to increase the capacity of the truck.

Obviously by putting the side boards, you can increase the volume of the truck, you can increase the productivity of your truck and you can reduce the cost you can reduce the production cost. But this will be only for short run. So, look into from a longer time perspective, you can see that in the longer run, you are actually abusing your machine, when you overload the machine beyond the safe operating weight, what will happen is?

Your tyre's will be abused all the other components of the machine it will be abused, it will result in more wear and tear and it will result in premature aging of your machine. So, this will result in

additional cost, huge cost of replacement of your machine at a earlier age itself. So, that is why we will not say much by just loading the machine or overloading the machine beyond its safe operating weight that you should understand. It will result in premature aging of the machine and it will result a huge loss to you by driving you for earlier replacement of a machine with a new machine.

So, next is volumetric measure, so, to express the capacity of the machine on volumetric basis. So, there are certain terminologies which I am going to expose you the struck measure, heaped measure, loose cubic meter, bank cubic meter, compacted cubic meter. So, these are the different terminologies we use related to volumetric measure, we will see what are these one by one in the upcoming slides.

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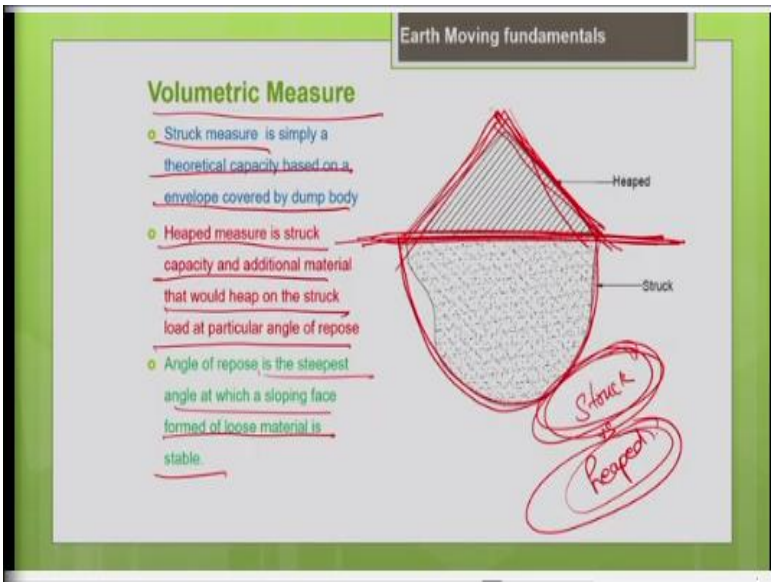

So, first is the struck measure. See, basically say for example, you have the bucket of your excavator, so you are going to excavate the load, you are going to load the bucket of your excavator, how do you express the volume of the bucket? See basically, there are different ways to express the volume; either you can express it on the basis of struck capacity or heaped capacity.

So, struck means, so you are going to strike off and measure what is the actual volume occupied by the bucket, so that is, your struck capacity. You strike it level the surface and measure the capacity that is struck capacity. So, it is nothing but the theoretical capacity based on the envelope covered by any structure, any dump body or anything. So, it is a theoretical capacity.

So, basically in the practical scenario, so when we load any bucket or any load the truck we never struck it level and then measure. So, we are not interested in struck capacity, what we are interested in is heaped capacity only. Normally when we load a bucket or load the truck, we heap the material at a particular angle of repose depending upon the material type, so we are interested in this heaped volume only.

So, heap measure is nothing but struck capacity as well as the additional material that would heap on this struck load at a particular angle of repose. So, angle of repose is the steepest angle at which the sloping face formed of loose material is stable; it will vary from material to material. So, this is what is the; difference between the struck capacity and the heap capacity. So, struck means we are going to struck off level and measure that is struck capacity. Heap means, you heap the material at a particular angle of repose and measure the volume. So, very commonly we use only the heaped volumetric measure.

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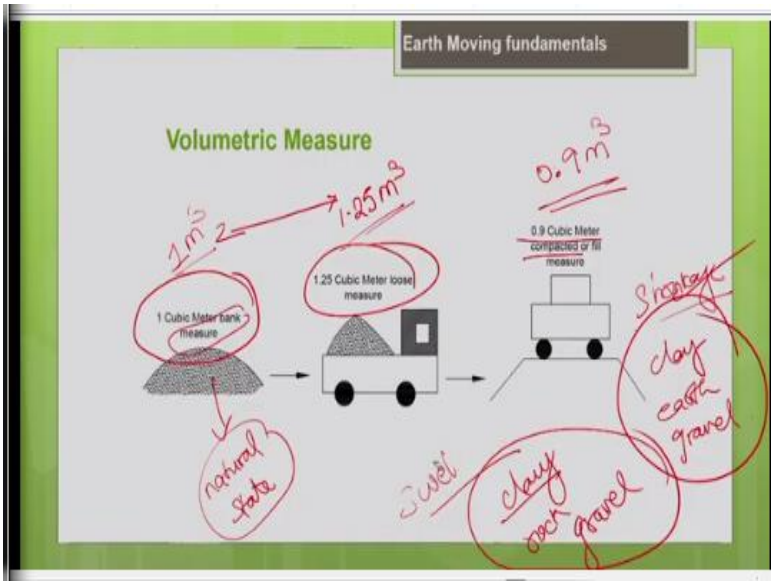

So, what are the other different ways of expressing the volume of the material? So, you know that the same quantity of material can occupy different volumes based on how you handle the material, say this is 1 cubic meter of material volume in the natural state of the material. Natural state in the sense, see before you excavate the earth with any earthmoving equipment the earth is in the natural

state. So, that is called as a bank state or natural state, before it is excavated it is called as bank measure or it refers to natural state of the material.

So, let us say it is 1 cubic meter; it occupies 1 cubic meter, now to excavate the material with excavating equipment and load it. So, once you excavate it what happens, the material gets loosened, so the more voids will be created, now it will expand and occupy more volume. So, you can see that the loosened volume is 1.25-meter cube, you can compare in natural state is 1-meter cube, in loosened state it is 1.25-meter cube.

It depends upon a type of material; this volume will vary depending upon the swell factor of the material. So, the swelling ability of the materials will vary. Say for example, your clay will have different swell factor, rock will have a different swell factor, gravel will have the different swell factor, and it will vary from material to material. So, how much is the swell factor you can get it from the literature for the particular material type.

Similarly, now you compact the material, say for example, when you prepare the subgrade for the roads, you compact it. So, when we prepare the earthen embankments you compact the material with the rollers. So, when you compact it properly, now you can see the volume will be 0.9-meter cube, so now the volume has reduced. So, the shrinkage has happened because of compaction, the voids are eliminated.

So, how much it will shrink, that depends upon the material. Clay has it is own shrinkage as I told you the earth, the gravel everything has it is own shrinking ability. So, you have to do some geotechnical investigations to study what is a swell factor or I mean shrinkage factor or you can take it from the literature. There are lot of information's available for different types of materials related to swell factor and the shrinkage factor of the material, you can make use of those values for your estimations.

So, one thing you have to keep in mind is when you do the volumetric estimations, so when you do your productivity estimation, when you are using the when you are expressing the volume of the particular materials, you should maintain some consistency.

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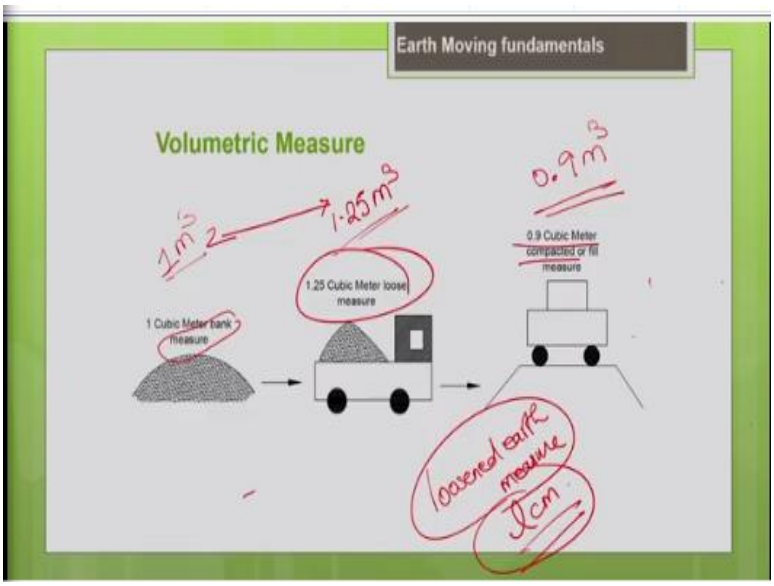

Say for example, you are going to estimate the productivity in terms of loosened earth measure. So, we want loosen the cubic meter. So, in that case, what you have to do consistently you have to use this particular volumetric measure. So, when you do the estimations of your productivity, you have to consistently use the volumetric measure. So, you should not mix up the terminologies. And there are certain factors which will help you to do these consistent calculations, let us see that.

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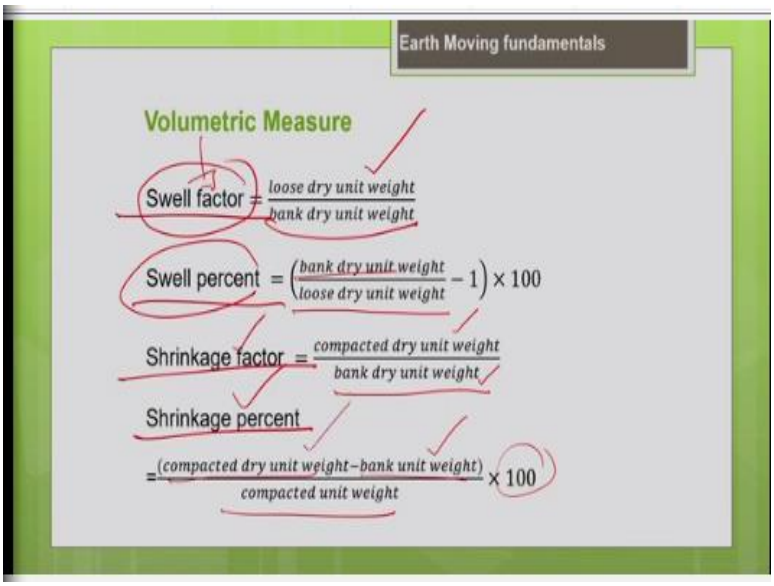

See as I told you swell factors, shrinkage factors, so all these things helps you to make some conversions, let us see what are those conversions? So, swell factor is nothing but it is the ratio of loose dry unit weight to the bank dry unit weight of the material. So, how much the material

expands or swells from it is natural state that is a swell factor. So; ratio of loose dry unit weight to the bank dry unit weight.

So, you can also express it in percentage, it is nothing but bank dry unit weight minus loose dry unit weight divided by loose dry unit weight into 100, so this is how you calculate the swell percent. Say for example, if you know the natural or the bank unit weight of the material. So, once it is disturbed excavator, in the loosened state you do not know what is the unit weight of the material?

So, from the literature, there are some tables which provide you the swell factor of different types of material. So, from the literature, you can take the swell factor for the particular material when using this swell factor you can calculate what is the it is loosened unit weight. So, that is the significance of these factors, these factors can see in the conversions, so that you can use it for the consistent calculations of your volume or the productivity when you make the estimations.

Similarly, shrinkage factor, so from the bank dry unit weight how much it has reduced in volume. That is what you are trying to find by the measuring the shrinkage factor. Shrinkage factor is nothing but compacted dry unit weight divided by bank dry unit weight. So, you can also express it in percentage, it is nothing but compacted dry unit weight minus bank dry unit weight divided by compacted unit weight into 100.

So, this gives you the shrinkage percentage. So, if you know the bank unit weight, if you do not know it is weight after compaction. So, depending upon the material type, if you know the shrinkage percentage, so from that you can calculate the compacted unit weight of the material. So, this helps you in simple conversions for your estimations of volume and the productivity.

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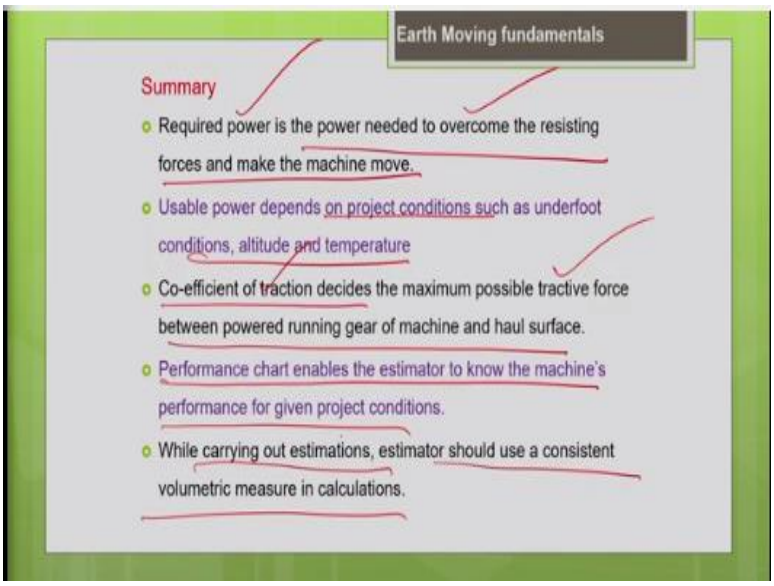

So, now we have come to the end of this lecture. So, let me try to summarize what we have discussed so far. So, you should know that the required power is nothing but it is the power needed to overcome the resisting forces in your project site and make the machine move. So, depends upon what are all the resistant forces in your haul route. So, what is the surface resistance, penetration resistance, grade resistance all these things you have to take into account.

So, then you have to find what is the tractive effort needed or the power needed to overcome these resisting forces. Then usable power, usable power it depends upon the underfoot conditions in a project site and the altitude and the temperature. So, it varies depending upon your project site. Then coefficient of traction it decides the maximum possible tractive force between your powered running gear of the machine and the haul surface.

So, out of the total power of the machine, how much power is going to be usable for doing your work it depends upon the coefficient of traction of that particular haul route. It depends upon the grip between the machine and your the haul route, so that is going to decide the usable tractive effort. Then performance chart help you to know the machine performance. So, for your given project conditions, I can know what is the speed of the machine from with the help of the performance chart.

So, as I told you when you do the estimations of your productivity, and the volumetric estimations, you should use a estimator should use a consistent volumetric measure in the calculation. So, there are different ways to express the volume you know that, loosened cubic meter, bank cubic meter, compacted cubic meter. So, whatever measure you are going to do, use, you have to use it consistently throughout your calculations.

So, you can make use of the swell factors, shrinkage factors of the particular soil type to know the corresponding values, you can use it for the conversions, which will facilitate you to do the estimations.

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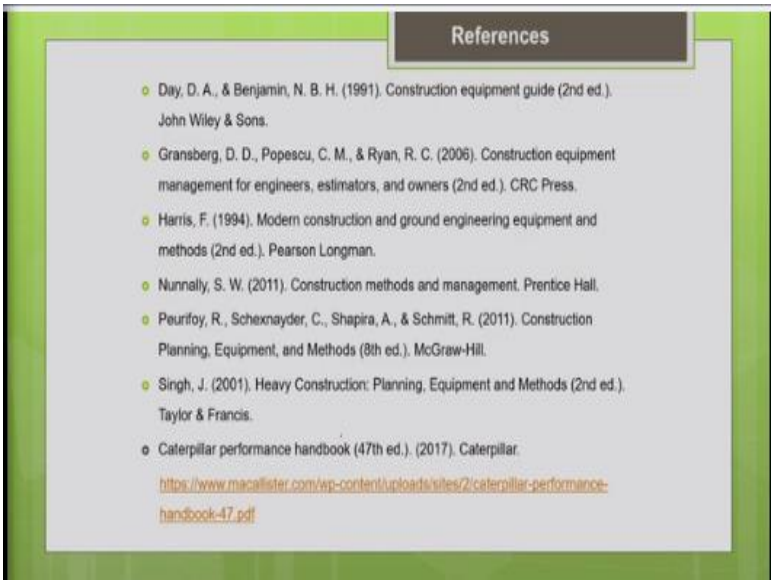

So, these are the references which I have used for this particular lecture. So, in the next lecture we shall discuss about the earthmoving equipment**.** So, firstly we will discuss about the bulldozers. So, what are the applications of bulldozers? How to estimate the productivity of bulldozers? What are the factors which affects the productivity bulldozers? All those things will be discussed in the upcoming lecture, thank you.