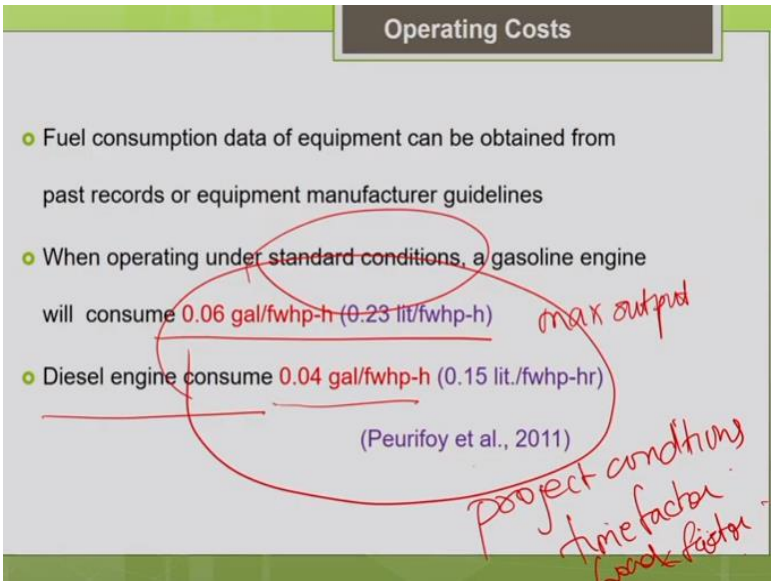

So these are the theoretical values which we have determine from the literature. So the literature also gives you some standard values so when a machine is operating under the standard conditions a gasoline based engine will consume 0.06 gallons so if gasoline per flywheel horsepower hour. In SI units if you see 0.23 liters per flywheel horsepower hour so if the machine is going to be diesel based engine it will consume 0.04 gallons per flywheel horsepower hour or in SI units it is 0.15 liters per flywheel horsepower hour.

So this is the fuel consumption rate given for 2 different types of engines one is gasoline engine other one is diesel engine. So this has been worked out for standard condition you can get it from the literature. So standard conditions mean your machine is working at maximum output so this value whatever if you are going to use this fuel consumption value for your project condition we have to adjust this value according to your project condition.

You have to adjust this value according to your project condition say for example based upon your time factor how much time your machine is going to work? Based upon a load factor for how much part of the cycle it is working at full power so based upon that you have to adjust these factors according to your project conditions that is what you are going to see. So you can make use of this fuel consumptions factors from the literature but you have to see a project conditions and accordingly adjust and use it.

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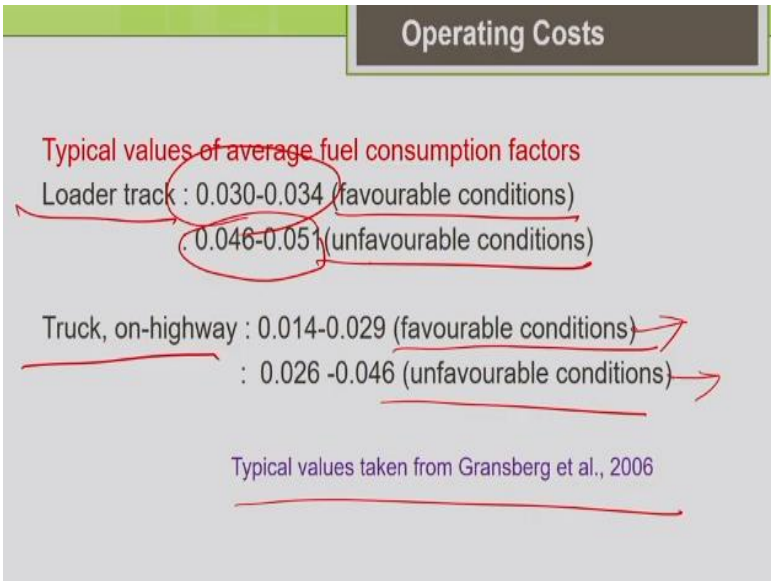

So these are typical values of average fuel consumption factors which are taken from the textbook by Gransberg et. al., it is given in the reference. So he has given this fuel consumption factors for different types of equipment's for different working condition favorable, average, unfavorable condition I am just showing only some sample values. So one thing you can see that the fuel consumption varies depending upon the type of equipment for a truck and loader if you compare the fuel consumption are relatively more for the loader.

You can say that track mounted loader consumes more amount of fuel when compared to the highway trucks. So it depends upon the nature of job it is doing, so it is doing little bit tougher job so it is fuel consumption will be more. Similarly, unfavorable condition you can say that fuel consumption is very high when compared to the favorable condition. so depending upon the fuel consumption is going to vary. As I told you already truck you can say that if you work it out on a very poorly maintained haul roads the fuel consumption is going to be high. Similarly, if you work on a properly maintained haul road it is fuel consumption is going to be less. So the definition of the project conditions also given in the literature accordingly.

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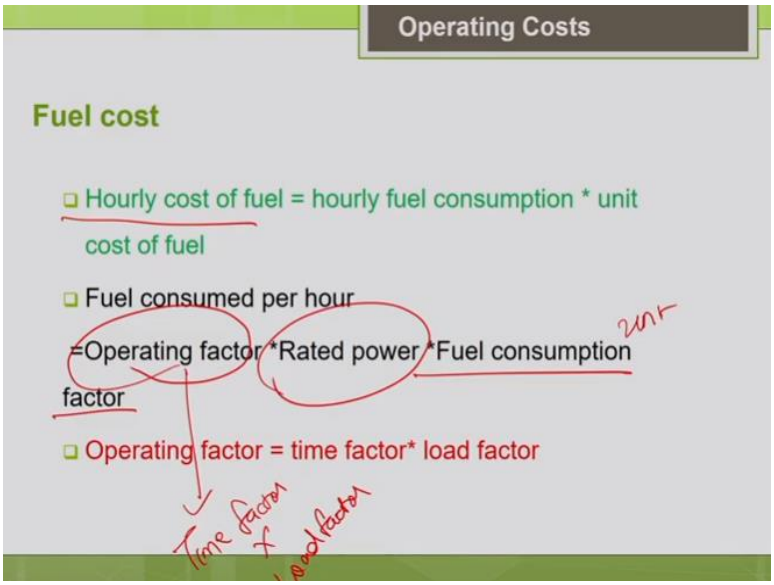

Next let us discuss about the how to estimate the hourly cost of fuel. Obviously estimating hourly cost of fuel we need to know what is it fuel consumption what is the hourly fuel consumption we need to know what is the hourly consumption multiplied by the unit cost of fuel. If you know these 2 things you can estimate obviously the hourly fuel consumption going to depend upon the type of the equipment and it depends upon the project operating conditions.

And the cost of the fuel will vary from face to face it depends upon the cost of the fuel in that local place. So this is going to influence your fuel cost estimation so how to find fuel consume per hour you can get the fuel consumption factor from any literature. From the equipment handbook of a many other source of reliable literature you can take the fuel consumption factor corresponding to the particular type of the equipment and project working conditions.

Then you have to adjust the fuel consumption factor according to your operating factor. So operating factor is nothing but your time factor multiplied by load factor, so according to your project condition you adjust And according to the horse power of a machine greater a horsepower obviously a fuel consumption will be more. So this is how we have to adjust the available fuel consumption factors which are available theoretically or from the handbooks according to your actual project conditions.

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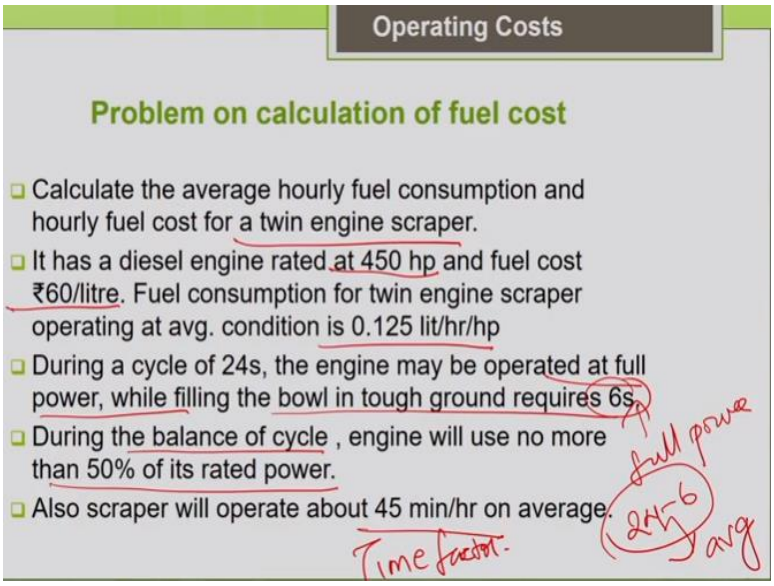

Now let us workout an example on how to estimate the fuel cost of the machine. So calculate the average hourly fuel consumption and the hourly fuel cost for a twin engines scraper machine. It has a diesel engine rated at 450 horse power and the fuel cost price is given as rupees 60 per liter. And the fuel consumption for twin engine scraper operating at average condition is a 0.125 liters per horse power per hour, the fuel consumption factor is given for this particular machine for the average working condition.

So you can directly visit because it is given in the question otherwise you have to look for the equipment handbook. Then during the cycle of 24 second of its production cycle you can see that engine may be operated in full power while filling the bowl in the tough ground. So it is filling the bowl the scraper is filling the bowl cutting the earth and filling the bowl for that it means 6 seconds.

So only during the 6 seconds time it is working at full power so the reaming 24 – 6 seconds during the balance of the cycle the engine will use no more than 50% of the rated power. So it is working at average power in the remaining part of the production cycle and it is working efficiency is 45 minutes per hour. So your time factor is also given here so with this input data now we are going to see how to estimate the fuel cost of the machine.

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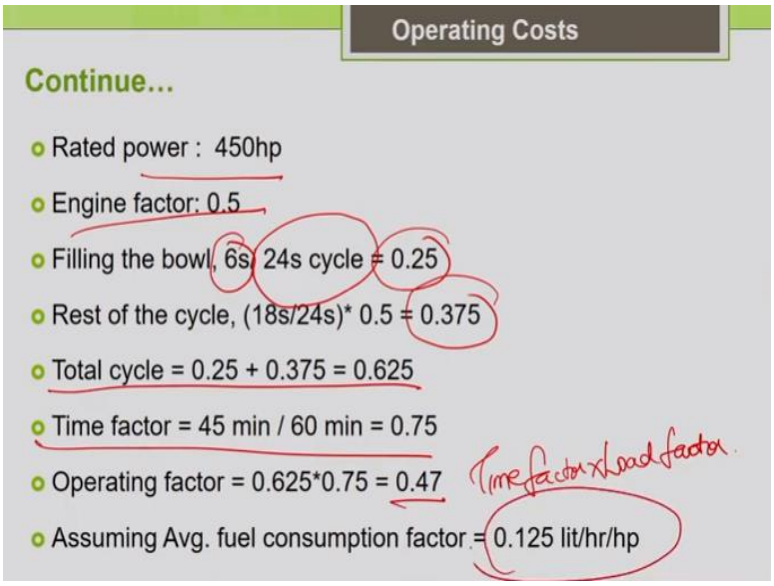

So the horse power of the machine is given the rated power 450 engine factor is given. So as I told you while filling the bowl it is consuming full power so it is taking 6 seconds out of the total production cycle time of 24 seconds to fill the bowl. During this cycle it is using full power, 0.25 into 1, so during the rest of the cycle that is 18 by 24 seconds it is using average power that is into 0.5.

So that will give you 0.375 now you find the total cycle, so while filling the bowl it is 0.25 during rest of the cycle just for hauling the material it is using 0.375. So the total cycle amounts to 0.625 now the time factor it is working for 45 minutes in 1 hour. So it is working efficiency is 0.75 now the operating factor is nothing but your time factor multiplied by load factor. So this is your load factor 0.625, this is your time factor 0.75 if you multiply you will get the operating factor as 0.47.

Assume average fuel consumption factor so it is given in the question the fuel consumption factor for this particular type of question for average working condition it is given as 0.25 liters per horsepower per hour.

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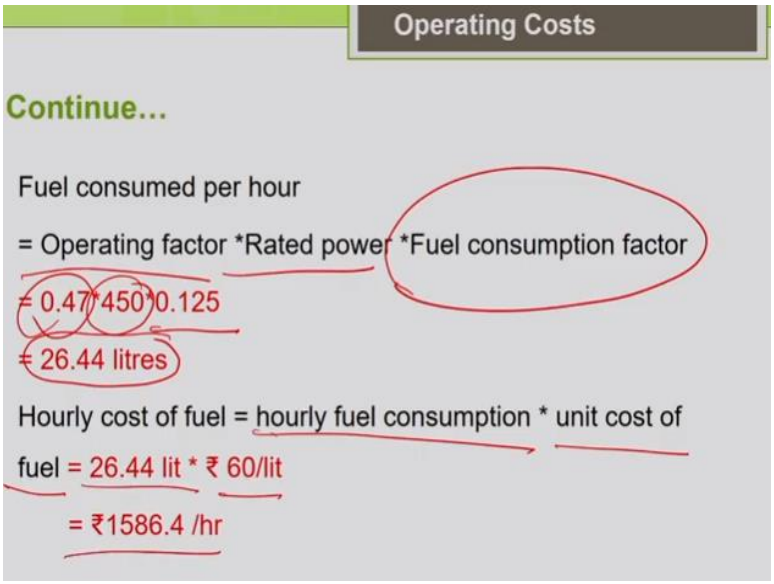

Now let us find what is the fuel consume per hour? So the operating factor multiplied by rated power into fuel consumption factor. So this fuel consumption factor which is determined for the standard conditions may be we are going to adjust it according to your project operating factor and the rated power of the machine. So the fuel consumption factor is nothing but 0.25, it is per horsepower per hour your horse power of the machine is 450 and the operating factor is 0.47.

So your fuel consumption per hour is 26.44 liters now what is the hourly cost of the fuel? Okay you know the hourly fuel consumption multiplied by the unit cost of the fuel. So it is nothing but 26.44 liters multiplied by rupees 60 per liter. It gives you rupees 1586.4 per hour so this is your hourly cost of fuel estimated for this particular machine. So let us continue our discussion that the estimation of the lubricating oil cost.

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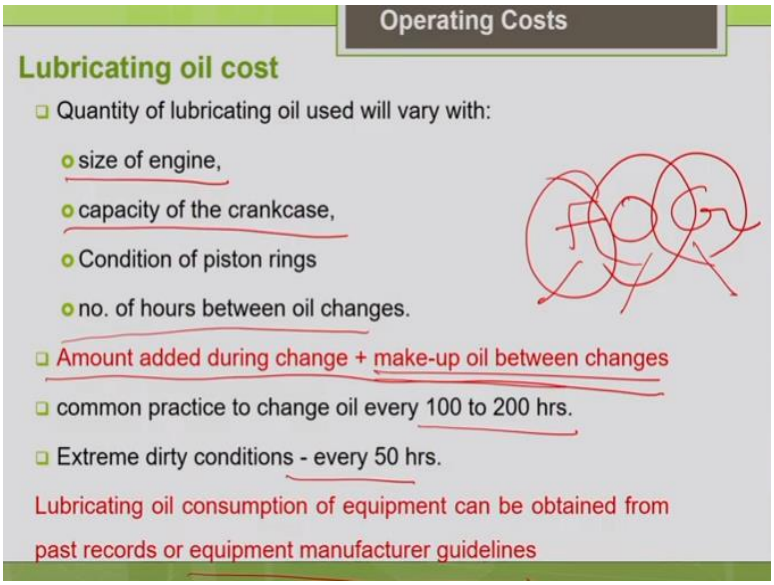

As we know that how much quantity of lubricating oil is needed it will vary it depending upon the size of the engine, the capacity of the crank case obviously. And condition of the piston rings and also depends upon the project conditions here. So if the project working condition that are extremely dirty. In that particular case we have to change the lubricating oil very often. So everything depends upon the project working condition and depends upon the company policy like the interval between the oil changes number of hours between the oil changes.

It depends upon the company policy normally you can say that it is common practice to change oil every 100 to 200 hours. But if the conditions are very extremely dirty in that case even for every 50 hours we have supposed to change the lubricating oil. Everything depends upon the project working condition and also depends upon the company policy also. Then the total lubricating oil the amount of lubricating oil is equal to the amount added during the change plus the makeup oil between the changes.

That means the amount of oil needed for a complete change of the lubricating oil and in between we just fill the small gap in between that is called as make-up oil between the changes. Just to fill the small gap left so every time we do not completely change it so we just fill the gap in between at the particular frequency only we do the complete change of the lubricating oil. So the total amount of lubricating oil needed will be the total amount needed for the complete change plus the make-up oil between the changes.

So this information also we can get it from the past experience records, for the similar type of the engine or similar type of the machine we might have past records about the machine amount of the lubricating oil consumption or you can go by the equipment manufacturer guidelines. So let us say for example if you go through the Caterpillar performance handbook, so for every model of a machine manufactured by them, for different operating conditions.

So they have given you what is the amount of the lubricating oil consumption per hour so not only lubricating oil we call it as FOG. So filter, lubricating oil and grease so the hourly consumption of filters for every model of machine and hourly consumption of the lubricating oil for every model of the machine and hourly consumption of grease for every model of machine manufactured for the different project conditions or operating working condition.

You can get the information from the Caterpillar performance handbook then we can just multiply by the unit cost of the lubricating oil or the filter or the grease to get the corresponding the hourly cost of the consumables. So the manufacture guidelines can provide you the sufficient information to get this data.

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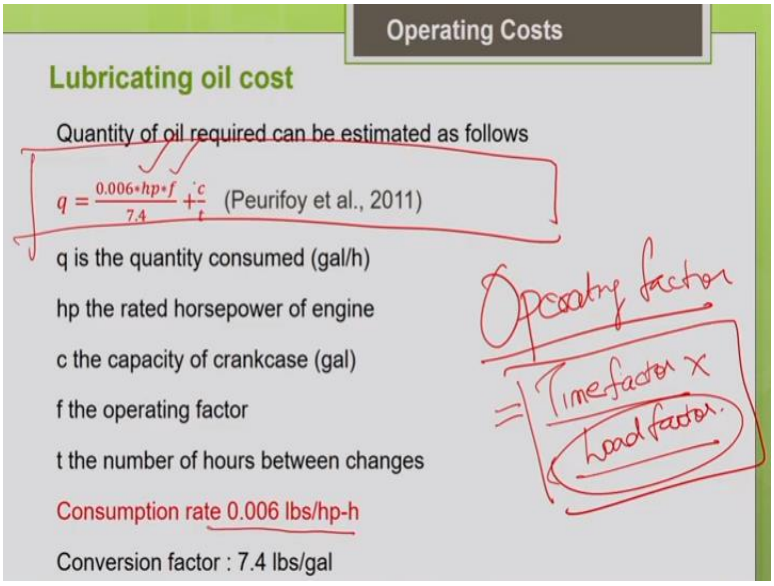

So another the thing is we also have this theoretical formula available in various literature how to estimate the lubricating oil.

$$q = \frac{0.006 \times hp \times f}{7.4} + \frac{c}{t}$$

So this is one such formula you can see q is the quantity of the lubricating oil consumed so in gallons per hour. So this 0.006 is the consumption rate of lubricating oil is 0.006 pounds per horsepower per hour. So it depends upon the horsepower of the engine.

So this 0.006, so we are going to adjust this value according to our project conditions say for example depending upon your horsepower of the engine you have to multiply it on 0.006 by horsepower of the engine accordingly. Similarly depending; upon the project condition say for example depending upon your operating factor. So I have discussed about this operating factor already operating factor is nothing but your time factor multiplied by load factor.

So how long your machine is going to operate in 1 hour, what is the working efficiency that is your time factor. And load factor is nothing but your production cycle for how much duration the machine is going to work at full power. And for how much duration is working at average power or the lesser than the full power. So if you know that we can calculate the full power so the product of these 2 will give you the operating factor.

So according to your operating factor you have to adjust this theoretical value 0.006 so then another thing is a crankcase capacity that will depend vary from machine to machine. So according to crankcase and between the number of hours in the changes that depends upon your project working condition. Whether it is too extremely dirty condition then we have to change it frequently and also depends upon the company policy as I told you earlier.

So the number of hours between the changes and this 7.4 is a conversion factor so this q is nothing but the quantity of oil consume in gallons per hour. But the consumption rate is a pounds per horse per hour so the conversion factor is 7.4 pound per gallon. So this formula you can estimate a lubricating oil for a project condition. So whenever you take some theoretical value you have to adjust it accord to your project conditions based upon the horse power of an engine.

Based upon; an operating factor, based upon the crank case capacity, based upon your company policy of number of hours of the changes of lubricating oil. So this is how we do so similarly this formula where we are estimating the quantity in gallons per hour. So I have just converted same formula in SI units so that we can estimate the quantity in liters per hour.

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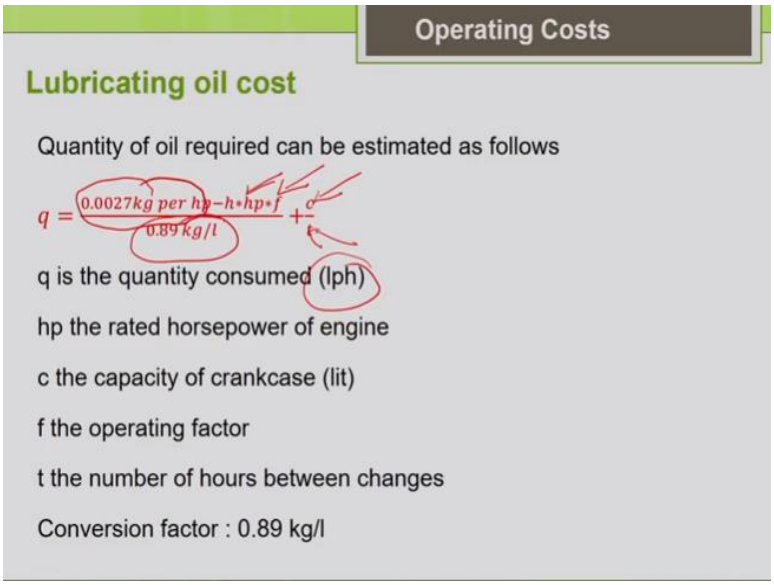

That is the only difference so here you can see the consumption rate is 0.0027 kg per horse power. Accordingly, you have to adjust according to your conditions into horse power into the operating factor into the plus crankcase capacity divided by the number of hours between the changes. And the conversion factor here is 0.89 kg per liter so the final quantity you will get it in liters per hour using this formula.

$$q = \frac{0.0027kg\ per\ hp - h \times hp \times f}{0.89\ kg/l} + \frac{c}{t}$$

So this is the theoretical formula available in the literature so that you can estimate your lubricating oil per hour.

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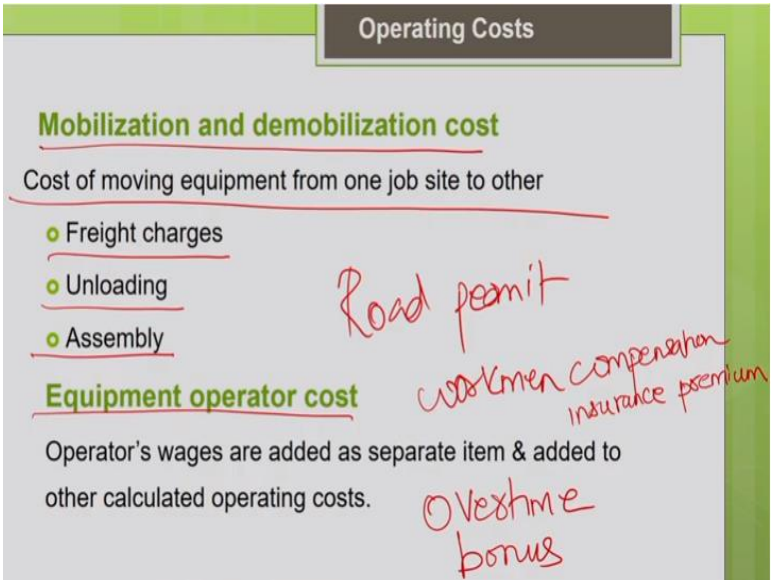

So the other important component of the operating cost is the mobilization and the demobilization cost. So already we discussed about the mobilization say when we purchase a machine, so the initial cost is inclusive of all the freight charges to procure the or mobilize the equipment to your project site. So apart from that you may have to shift the machine from one project site to other project site.

So in that site you have to calculate the mobilization cost separately and it will be included in the operating cost. So the cost of moving the equipment from one job site to other so this includes your freight charges your transportation charges and as well as your other loading charges and the unloading charges of the machine. So loading unloading charges and, the road permit so even the road permit charges for mobilizing the equipment to the particular project site.

And getting the equipment ready or installation assembly charges everything comes under this mobilization and the demobilization cost everything should be accounted. Accordingly, you can estimate the hourly cost. Now next is an equipment operator cost this includes your normal operator hourly wages. So normal hourly wages of the operator and also you have to include all the other benefits let us say for example is over time charges benefits other bonus what he gets.

Everything should be included under the equipment operator cost even the workmen compensation insurance premium which the employer pays on the behalf of the employee or the worker. So that premium is also included in this workmen compensation insurance premium so everything is included in this operator cost and you have to calculate the correspondent hourly operator cost. So operator wages are added as separate item and added to the other calculative operative cost.

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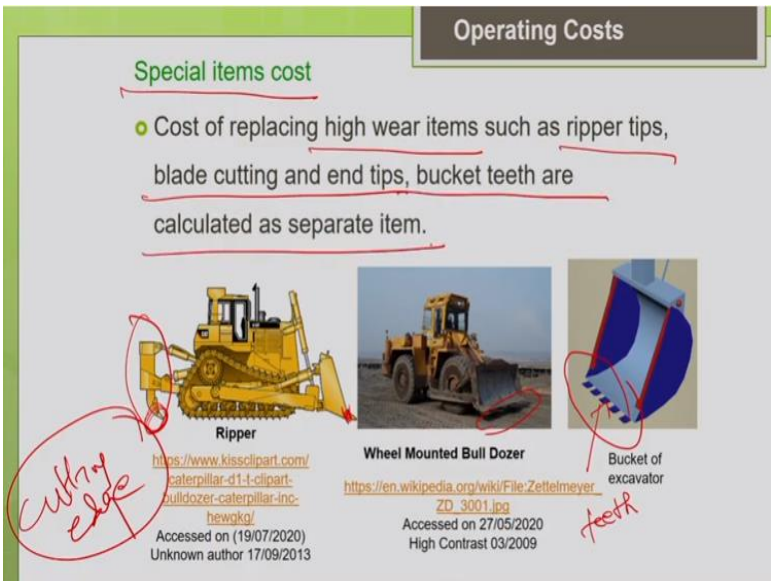

So the component in the operating cost is a special items cost means they are called as high wear items. That means they deteriorate they are subjected to wear and tear at the very faster right. They deteriorate at the faster rate their life is very shorter say for example the Bull Dozer blade. At the bottom of the blade you can see the cutting edge so the cutting edge it is just bolted at the bottom of the Bull Dozer blade so this cutting edge gets worn out fast depending upon the project working condition.

It is a very rough or severe working condition wear and tear will be very faster so the cutting edge gets worn out faster. We have to replace the cutting edge at a very shorter time interval, so generally we do not replace the blade very frequently we just replace the cutting edge frequently. So these are called as the high wear item similarly your ripper which we use it for loosening the earth at the booth of the repair you can see the tip.

This tip also gets worn out fast we have to replace the tip in a shorter interval this picture clearly shows the cutting edge at the bottom. So another thing is your, this is the excavator bucket so you can see the edge of the bucket you can see the teeth of the bucket teeth. This also gets worn out faster we can they are just bolted down to the bucket so you can just replace it very faster as its gets worn out.

So basically these are high wear items which gets worn out faster so special item means cost of replacing the high wear items which is the ripper tips, blade cutting and end tips your bucket teeth all these are calculated as the separate item or the special items.

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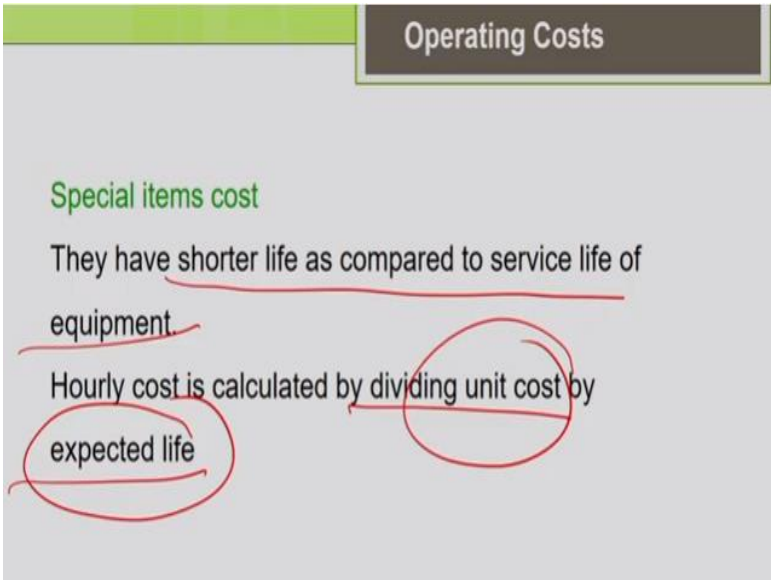

Because they have shorter life when, compared to the service life of the remaining part of the equipment. So for this also you have to calculate the hourly cost to know the hourly cost you should know the unit cost of the item and you should divide very expected life of these items. So this information you can get it from your past records or from the manufacturer. So manufacturer handbook will provide you the information on the expected life of this particular unit for different operating conditions.

So based upon that you can get the information and also the unit cost you can get from the manufacture so based on that you can get the hourly cost of this special items.

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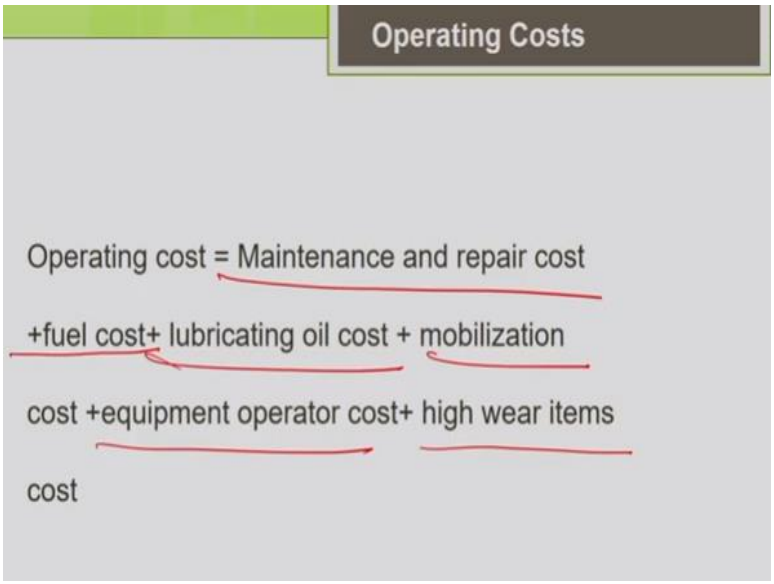

So what are all the components so far we have discussed under the operating cost let us summarize. So maintenance and repair cost your fuel cost, lubricating oil cost all these are consumables, the mobilization cost, equipment operator cost and cost of special items of high wear items. So all these things we have operating cost of the machine.

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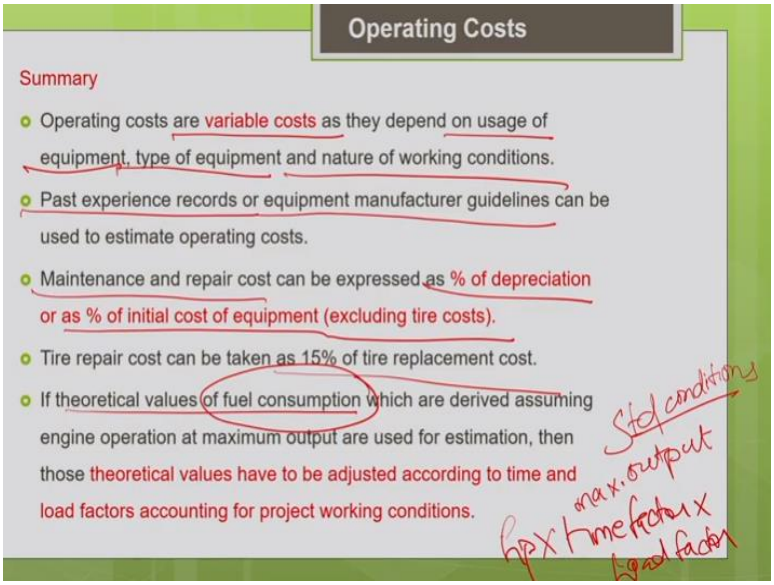

So let us just summarize with this we are coming towards the end of the lecture 4. So basically as I told you in the beginning the operating cost is highly variable cost unlike ownership cost which are relatively fixed. Operating cost are highly variable because they depend upon the usage of the equipment more you use the equipment more the number of operating hours the fuel consumption is more the repair and maintenance will be more.

So everything depends upon the usage depends upon the type of equipment if it is going to be the highly mobile equipment it is operating cost will be more. So depending upon the nature of the job nature of the working condition and the same machine will put into severe working condition and put into normal working condition you can see there will be huge difference in the operating cost.

We discussed all those things with various illustrations so this information of the operating cost you can get it from the past experience records. If you have accounted or if you are maintaining records properly from your own past records you can get the information on similar equipment or you can go with the guidelines given by the equipment manufacturer in the equipment handbooks.

Another important thing to be noted is your maintenance and repair cost of the equipment, it can be expressed either as a percentage of the depreciation. Or it can be expressed as a percentage of the initial cost of the machine excluding the tire cost. Because tire repair will be considered separately because, the life of the tire the deterioration rate of the tire, everything is going to be different from the remaining part of the equipment.

So when you calculate the maintenance and repair cost of the equipment they exclude the tire cost from that. So if you do not have much information the tire repair cost you can take it as you can just add 15% to the tire replacement cost to get the tire repair charges. And another important thing to be kept in mind if you; are going to use the theoretical values of fuel consumption from some literature.

So for the particular type of machine we have chosen the fuel consumption factor from a literature where it is derived based on standard conditions or maximum output rate. So when the fuel consumption factors which are given in the literature are given based on standard conditions where the machine is working at the maximum output rate. Then you are supposed to adjust those fuel consumption factors according to your project condition.

So how to adjust it according to the horsepower of the machine, you have to multiply the fuel consumption factor and another important thing is according to the time factor and load factor. So which is nothing but the operating factor so according to your operating factor so you have to adjust those theoretical values and so that it can reflect your project conditions accordingly.

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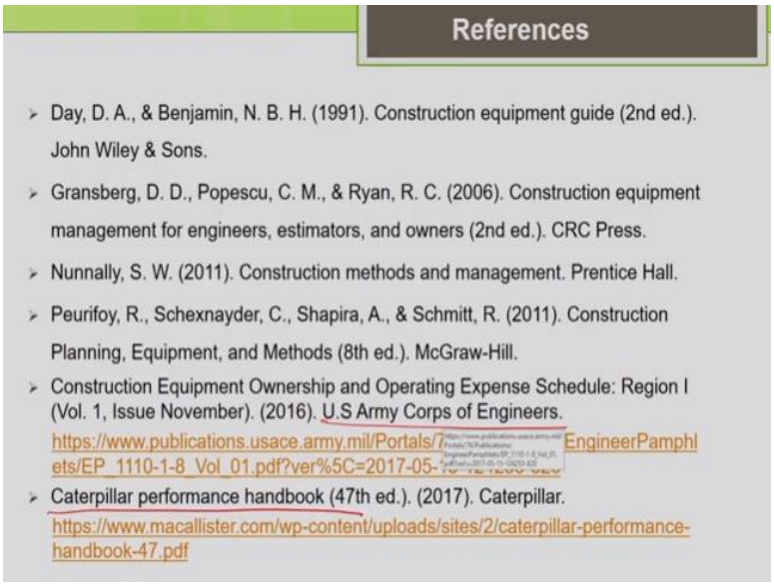

So with this we have come to the end of the lecture 4 so these are the reference which I have to use for this lecture 4. So basically I would like you to download this Caterpillar performance handbook even the link is given. So as I mentioned earlier lot of information on the fuel consumption your filter, oil, grease consumption for different models of machine and the repair factors, the tire life.

So all this values you can get the much clear information by going to this handbook and also there are lot of illustrations worked out which will give you more information to learn this the subject. So there are also other handbooks not only caterpillar performance handbook there are other handbooks supplied by different manufacturers. So you are free to download it and go through that and this is another handbook which is published by U.S army Corps of Engineers. This also provides a lot of information on how to estimate the equipment cost, thank you.