Mining Machinery
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Module - 08
Lecture - 45
Off - highway Trucks : Performance

Welcome back today. We will be discussing another lecture on mining truck. This is particularly for measuring and knowing about the performance as in our this course on mining machinery for mining engineers. The mining engineers main responsibility is to maintain the productivity. So that all the machinery they are targeted output that must be received; must be achieved.

Now, for that purpose, the performance that is how it is working need to be measured and only when you can measure, you can manage.

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So, this particular class is for introduction to the performance measurement of mining trucks. This is a as we know that is our main job. Here we have discussed the truck will be deployed for carrying material from the pit to the surface. So, it will be going with a payload on it up a gradient and then, it will have to overcome different resistances.

So, the performance mainly we will be looking forward to that is whether it is energy efficient that is for per ton kilometer, how much fuel is going to be used; is it exactly our performance with respect to which operational trouble, that is; is it a trouble free operations. That means, the within the that our stipulated time, is it going underground any breakdown. So, that means, what is the total utilization or that availability of this equipment, these are measured.

So, some of the things particularly the productivity calculations, we are not going to do it over here. Because that you do in your surface mining class in any way, that is how do you

measure the productivity and its compatibility with the shovel. Because the productivity of this will be depending on how it is being matched with the shovel. So, that part we are not discussing in today's class.

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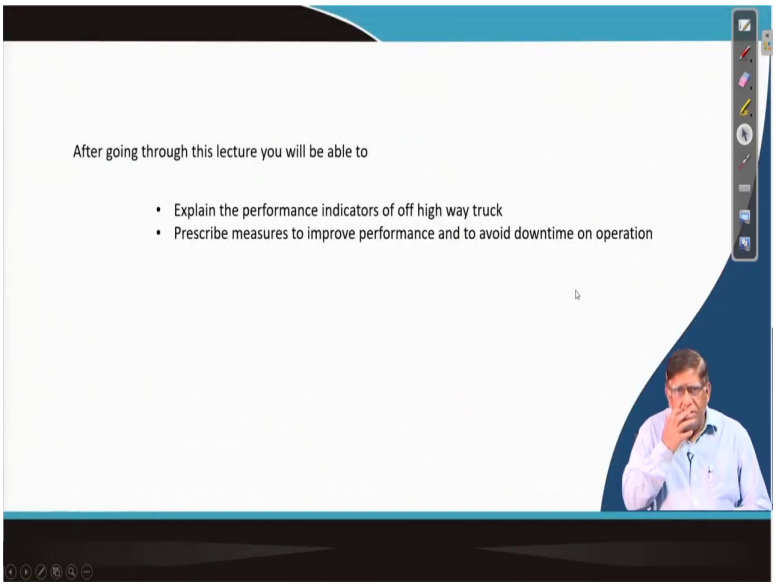

So, after going to this class, you will be able to explain the performance indicators of off high way truck and also, you will be able to prescribe that measures to improve performance and avoid down time. That in a surface mining operations, while you are going to utilize this machine, you know about the construction and then this operation and maintenance of this machines.

So, from that point of view, you should be able to prescribe that what are the conditions must not be there that or you must avoid in the surface mines. So that the performance can be improved or performance that required performance can be achieved.

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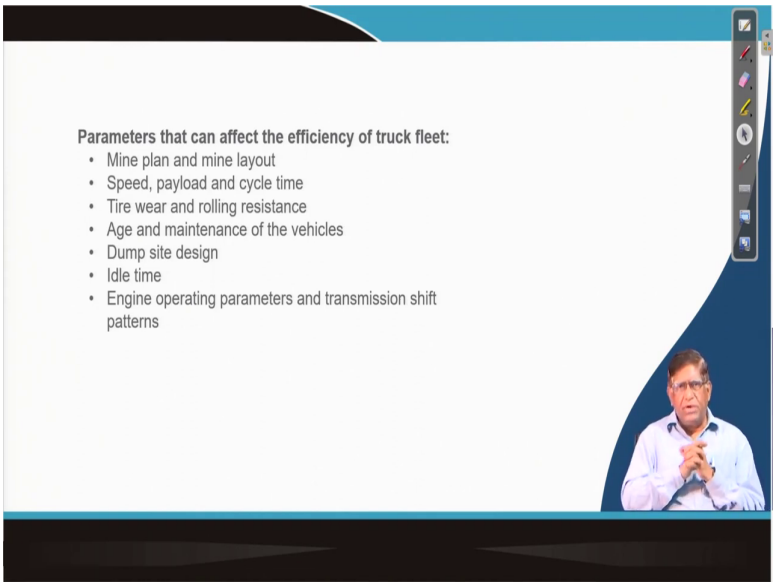

So, basically, this is a you will have to take care of what are the different parameters that will be affecting the efficiency of the truck. The efficiency of this truck will be as a it will be truck will be always working in a fleet. Because to serve 1 shovel, you may have to have depending on your side configurations 4 trucks, 5 trucks, 7 trucks depending on the situations how that it planned it.

So, that is why the parameters that will affect the performance of your truck, it depends on the mine plan and the mine layout. It is obvious that is a if the mine layout whether your mining of this say your 2 phases or in 1 panel or in 1 panel, 1 phase and then, whether this truck is going to serve any 2 shovels or 1 truck will be serving only a particular shovel.

So, that whole thing will be depending on the mine layout and then, this mine plan. Then, the other thing is most important is the speed payload and the cycle time. This is exactly the

parameters you have selected for when you design the mine, that is your the truck will be moving at what speed with load and without load.

And overall, what will be the cycle time depending on the mine layout, what is the lead distance that will determine. Then, also your the tire condition that is a very very important. In our last class also, we discussed how the tire effects. So, tire wear and the rolling resistance of the road surface.

So, that is what rolling resistance is a function of the how you have designed the haul road, what type of materials you use and what type of maintenance of the haul road you are doing. So, they will be affecting the performance of your truck.

And also, that is the with aging, whether you have been going on repairing and replacing some of the parts and then, you are running for a long time or your this is a new machine that will also affect. Particularly, you depending on your side conditions, what is exactly the manufacturers, they may prescribe a life. But you need to evaluate on your side whether that life which is how it can be extended or what will be the replacement time for a truck.

We are not going to discuss in today's class that how do you determine at what time you will have to replace a truck; but you must know that as the age increases, the performance and productivity of an equipment go down and there is always a time or optimal time at which you will have to discard and write off that machine and replace it with a new machine. So, that will have to be done.

And then, also this your as because you are carrying the over burden to a dump site. In the dump site, how you have designed that will affect the cycle time because how much time you will have to go to the dumping point and from there, how will you be returning. So, depending on that, your the total cycle time and that cycle time is directly affecting the perform productivity and performance. So, that is why the dump design also will be affecting the performance of your truck.

And then of course, the idle time that means, if your work organization in the mine is not proper and out of the shift hours, your machine is going to be more idle; maybe sometimes it is idle, it is returning to the this your shovel site and that shovel is still loading the previous dumper. It is not there, that is why it is going to just wait idle or sometimes during the shifts starting and shift ending, while your change of operator and takes place.

At that time also, the machine may get remain idle because it has nothing to do. So, that type of idle time will be definitely affecting your performance. Similarly, that your engine operating parameters that is a what are the that is a what is its temperature, what is its fuel consumptions; how the transmission is there, that is your whether how many gears you are changing, at which gear you are running that operating parameters of the engine also will affect.

So, and of course, the whole performance if you are selecting the right type of equipment for the right type of job or not. So, that is the matching of the equipment for the site condition is very very important. And of course, the performance under those conditions will be depending on the design of it. A mechanical truck will be behaving differently, a electric haul truck will be having differently or you are having a trolley assist truck that will be different differently; but we will have to measure that performance.

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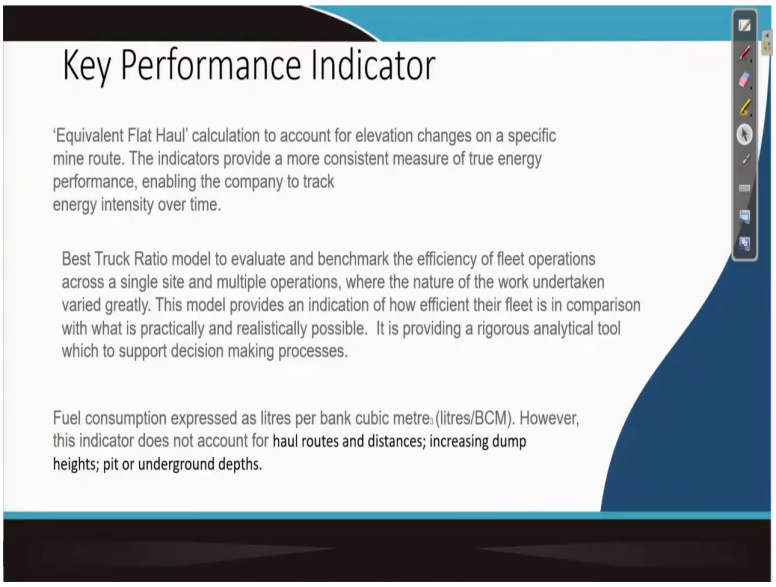

So, this is a key performance indicator, KPI. It is very very important. Now, you will have to do the study of your mine to determine what will be the key performance indicator, on the basis of which you will know that whether your truck is giving the expected performance or not.

One such parameter will be talking about today is equipment flat haul, that is your dumper is a taking the material from the pit to the surface. So, it is a having its a during its hauling, it has got a horizontal route, it has got also the incline route. There may be incline sectors 3-4-5 sectors or segments of the haul road may be inclined.

So, if you see that is your the total energy consumed, it will be increasing wherever you are going up the gradient and then, that is why there is a equivalent flat haul, that will be giving exactly in a month how much exactly the total kilometer or the total material, it has carried.

If you convert them to an equivalent flat haul, it becomes a good comparing for the performance of different months. So, that is why this parameter is used. Then, there is also one model called best truck ratio model, where you develop one benchmark and then, that is a what is the best performing truck and on the we compare the other with this benchmark.

So, that is where your this bench comparing with the benchmark or the best performing truck, you determine one best truck ratio. Now, that best truck ratio can also reveal that how a particular truck is working, we will be discussing that also today. And then, the fuel consumption because the if your haul road is properly designed, your that it is properly maintained, timings are ok and then, you will have to get a better fuel utilizations.

Now, that is why the how that fuel utilizations will have to be compared, it is done sometime by bench cubic meter; that means, how much material is from the bench is a you have exactly removed by using how much liter. So, this ratio of liter per bench cubic meter gives a idea of how the truck is consuming energy.

So, if you can find out that is the that an engine will more fuel, it will require more fuel, if the engine is not performing well as it is there that. If the efficiency of the engine goes down, then what will happen? For the same work, you will be consuming more fuel. So, if we are having the same type of same make same truck, but maybe of different age, then you will find that there is a difference in the your this fuel consumption.

So, these are the things in an that is your in the field, you need to observe and then, from there, the recorded things you need to take a planning decision for improving. So, this indicator when we say that this your how much liter per bench cubic meter, it gives a general overall idea because it does not take into account that what type of haul route has gone or

what is that exactly to what the height of dump, it has gone or that is how much dip, it has gone; it does not tell about its geometric locations or where it is there.

It is taking only in your phase how much block a volume, you have removed. So, that is why this is a there is a different purpose of this indicator, but it will not reflect. Because the same truck maybe that is this time, you have got a very high later of fuel is being there is the fuel consumed is rate is higher means you have used more diesel for that particular block of overburden removal.

Maybe due to that your this where you are dumping in the dumping yard, you are travelling along distance, you are handling there is you are taking long time, cycle time has increased. So, that is why when you take only the liter per BCM, the other operating factors are not revealed. So, whenever you are thinking of an indicator, you must see that these gives a general representation of other because otherwise, you cannot compare two situations which situations need to be improved.

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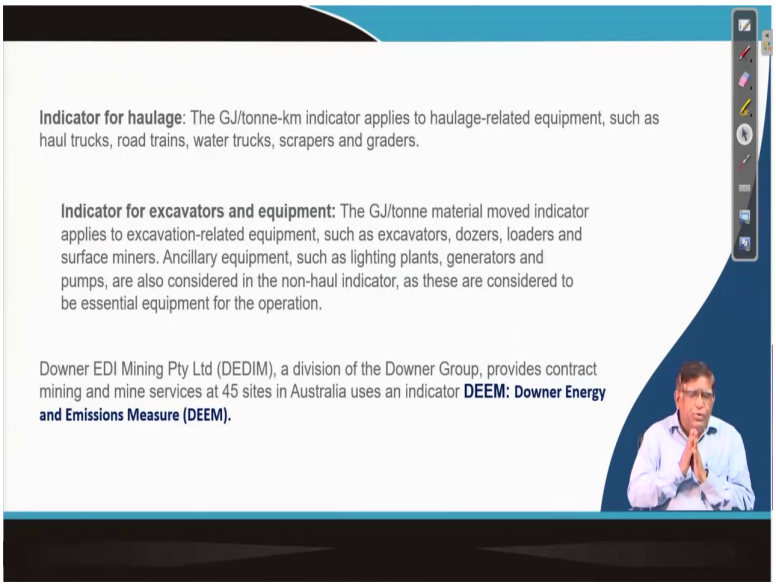

So, there is your another thing is some major unit is your giga Joule per ton kilometer. This is another indicator that is exactly how much calorific value is required for a ton kilometer and a it can be; it can be used for all other machines also, that is your as a from the total energy efficiency of your mind that can be also found with this indicator.

So, now this giga Joule per ton, this how much material is removed, this indicator it can be applied with a other equipment also like your excavators, dozers, loaders and other surface minor. So, this is a this indicator gives an idea about how exactly the machines are being used along with your dumpers.

So, but there are different way of expressing these key performance indicator out of which one company that is your Downer EDI Mining Private Limited in Australia, they developed a method; they say DEEM, DEEM is your Downer Energy and Emission Measures.

So, they not only take care of the your how much fuel is being consumed, also take care of how what is the emissions coming. Because whenever you are taking a diesel burnt vehicle in the mines, the diesel exhaust, diesel engine exhaust that has got number of toxic and then, they can give a lot of greenhouse gas emission which will be contributing to the your global warming as well. So, that is why the emission standards are also need to be taken care off.

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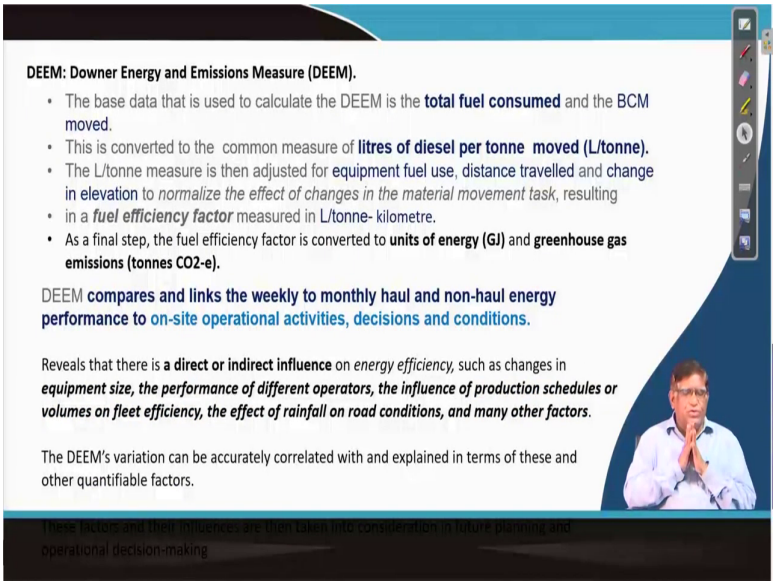

So, that is why that this new methodology that downer energy and emissions measures, they take the total fuel consumed and total bench cubic meter transported that they convert this into how many liters of diesel per tonne moved. So, from cubic meter, they take it to the per

tonne and then, this is adjusted with the fuel use and then distance travelled and then, change in the elevation.

That means, they bring it that your flat haul concept, by that exactly they normalize this parameter for having a comparative thing so that you can know that within your mine different equipment how they are performing or time to time, months to months how overall fleet and how overall equipment are performing.

So, this is a they are giving a this is a fuel efficiency a factor or efficiency factor of the engines indifferent machines can be compared. So, and also what they do? They find out the total unit of energy and then, total how much is the greenhouse gas emission emitted. All this whatever the greenhouse gas is emitted, they are converted to a carbon dioxide equivalent.

And then, they find out that is your giga Joule, how much is being consumed for per tonne of carbon dioxide equivalent. So, these gives a an indicator by which you can say that how exactly environmentally friendly mining you are doing or not. So, they compare this that are weekly, monthly and then that your they convert with the other operation say in a mining operations, there is a hauling operations as well as non-hauling operations like excavations that is your an other drilling these operations, there how much energy is consumed.

So, this particular indicator DEEM, they do compare with the other the time to time and then, you have got an idea how exactly your performance is going, as you are expecting your energy efficiency, your environmental performance, your safety maintenance all things can be together and this is the way how a systematic measurement takes place.

And then, they when they are doing it, it is exactly the performance many a times is a qualitative measure, that is a we say you are doing good, you are doing well. So, that a fuzzy such statements are also involved that we are better this month. When we say better this month, we do not know what better in what way. So, if there is a no accidents and anything from the to the traffic, then they will say it is a good month; but it maybe there, that month there may not be a good production also.

So, that means, not having any accident, when there is no production, it does not give a sense of a good performance from the safety point of view. You will have to eliminate or zero accident, when even you are doing the targeted production. So, that is why the performance of months, to months need to be compared and in sometimes, just only by telling that there is no accident, that does not show that the people involved or the leadership is doing well.

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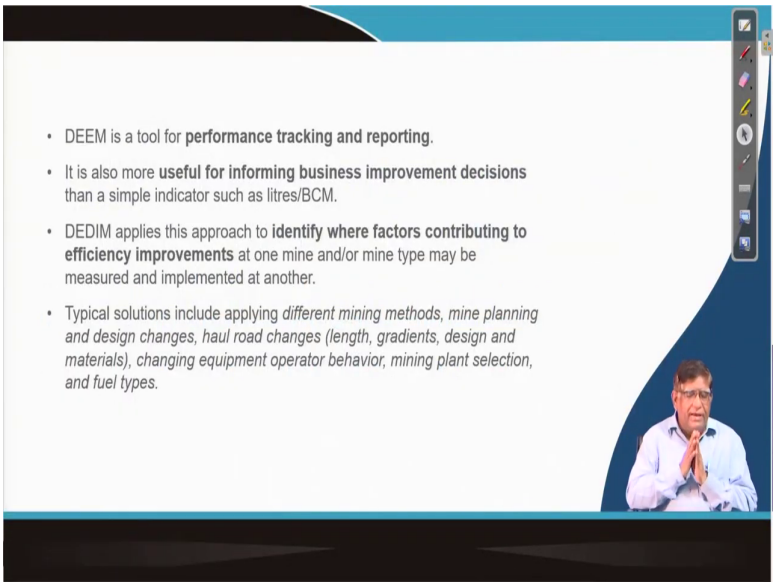

So, these are the things need to be considered over here. So, the DEEM this particular energy counting methods, they do this whole performance tracking and they do report in a very precise manner so that they quantified way you can know how the system is working. So, this is a basically they give the performance indication to the planning for the next operations.

So, because they will be identifying that which factor need to be improved for your better selection of the mining method and if deviation is required, whether the design change is

required, whether the haul road need to be changed. As we say that the haul road parameter may be its length, its gradient, its cross sections, how it is doing the drainage; if they need to be changed, you can find it out.

So, that even the equipment operator behavior that also get revealed. Sometimes the performance is also the operator dependent that is why nowadays, you find that the operator response are also monitored and measured and they give a feedback. So, they what type of fuel you have used, what type of exactly the overall whole scenario can be revealed.

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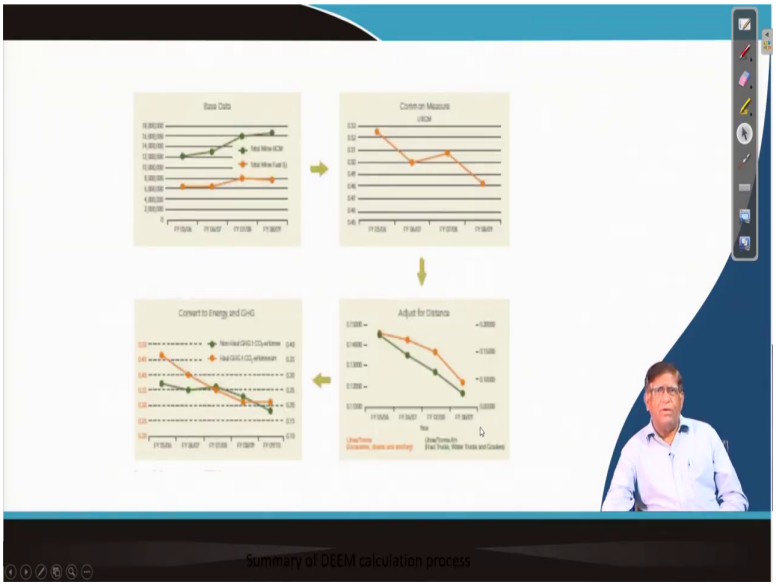

So, that is why whenever we tell that a in a dumper operations, you need to do the performance indicator; then, only you can make the whole overall systems over there. So, these are the under the DEEM, what they do they exactly collect the base data and then, they

make a basic analysis over there that how exactly that how much distance wise how it is doing that your total elevation wise how it is doing.

And then, they how much greenhouse gases emitted, converting all these things they do it

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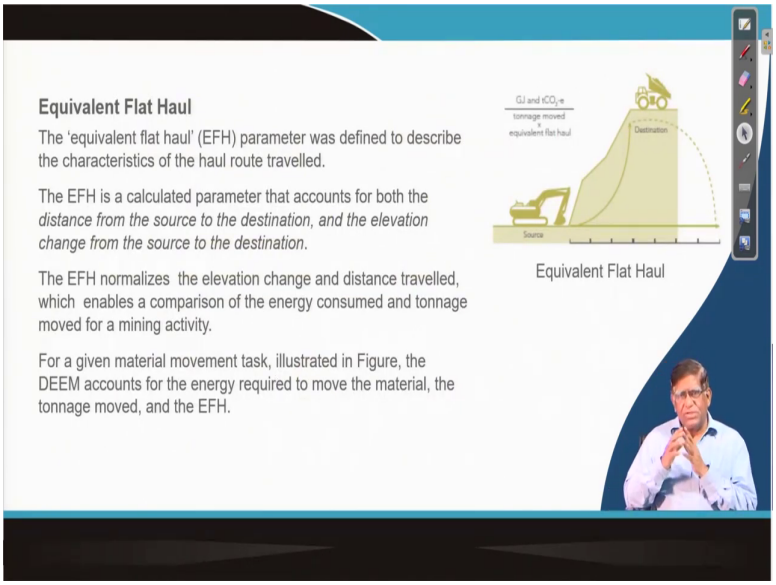

Now, the basic concept, when you are getting that distance travel that is your as you can see the truck will be travelling from say from the pit bottom to the pit top where they are dumping.

So, while going these ones that all this work which is that energy it has spent that can be brought to, that if it were not going up it would travel this particular length. So, that is called your the flat haul length and for that, total how much exactly your greenhouse gas has been emitted and the total the carbon dioxide equivalent has been done that taken care of.

So, if you are measuring the total giga Joule and the total carbon equivalent, then with that you find out that how much total tonnage has been removed. So, all these parameters are taken into over and then, they find out this as an indicator. So, this is a the your equivalent flat haul, it is calculated parameter that accounts for both the distance from the source to the destinations and the elevation changed from the source to the destinations.

So, this is taken into account and does it normalizes the elevation change and distance travelled, which enables a comparison of the energy consumed and tonnage moved for the mining activity. So, once this is done, then it becomes a easy for the calculating it as an indicator for any deviations from the expected term.

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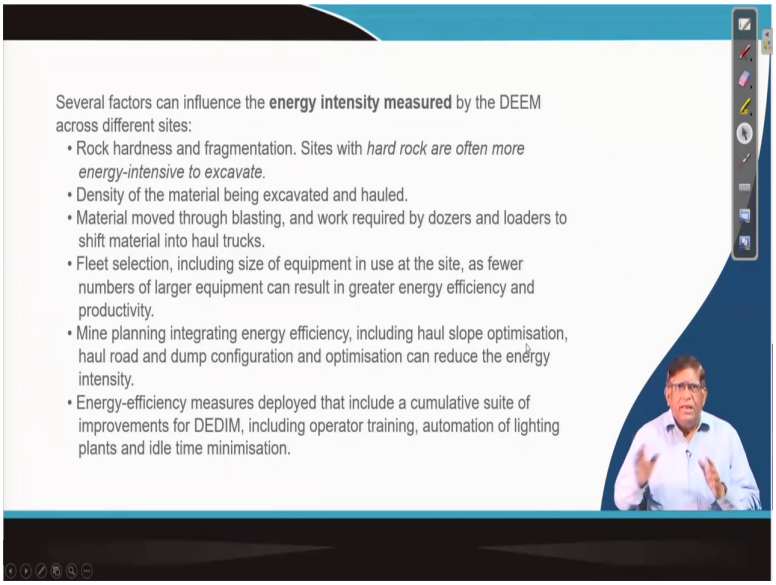

So, there are number of other factors that influence the energy intensity measured that by when you are you have done before a particular situations, you have converted it that flat

equivalent flat haul and for that how much energy has got consumed, this will be depending on the situations, whenever you say that is your that value energy consumed is going more, that does not mean that you are performing poor.

Because you will have to account that change that is exactly their your parameter has changed, maybe your working situation has changed. So, that is why you will have to take into account that what is the rock hardness and fragmentation; how the blasting has been done. Because that your type of rock, it is to be handled that will be also relating your energy consumption.

So, site with hard rock are often more energy intensive. So, if your boulders are coming; that means, if your boulders are coming, your number of trips can be different and then, if you are fragmentation is different, your the total number of trips will be going more and more energy will be consumed.

So, this requires; but thing is that sometimes if you are having a very big boulders, it will get take a long time by the shovel to load. So, that the cycle time will go on increasing. So, that is why the rock hardness and the how the fragmentation has been taken that is very important.

Then, density of the material excavated and hauled, the density of course the total load which is coming, the gross vehicular weight which will be there, it will be depending on the density and then, the gross vehicle weight only will be putting the resistance which will have to be overcome and which is related to your energy consumptions. Then, material moved through that is your; that is your how you have done the blasting and then, how you have deployed dozers and loaders to shift onto the truck, this is also a point to be taken care of.

Then, your fleet selection that is how many number of dumpers and with a particular shovel you have given and that is your what is the size of them that is another thing as a in while you are doing a surface mine planning, in that you determine That is a depending on the distance to be that material to be taken and then come back and then, what is the size of this

equipment that will be exactly size of the equipment and the number of equipment that fleet selection is important.

Then, mine planning, integrating energy efficiency that is including the haul slope optimization, haul road and dump configurations that could be there, then energy efficiency measures that will include the cumulative suite improvement of that your that your DEEM applications.

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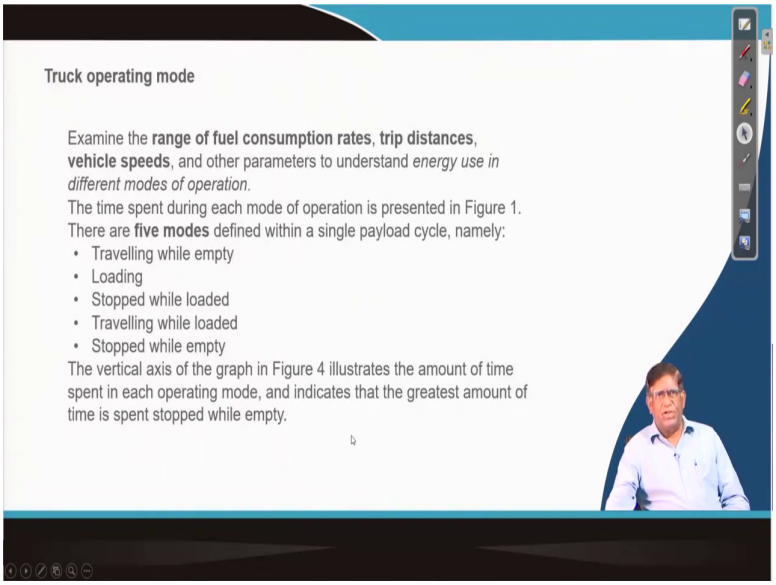

Similarly, your truck operating mode that is whether it is travelling your on the empty or whether it is travelling loaded or how many times, it has stopped during the running and then, what is a how it has travelled this whole thing will be effecting your efficiency.

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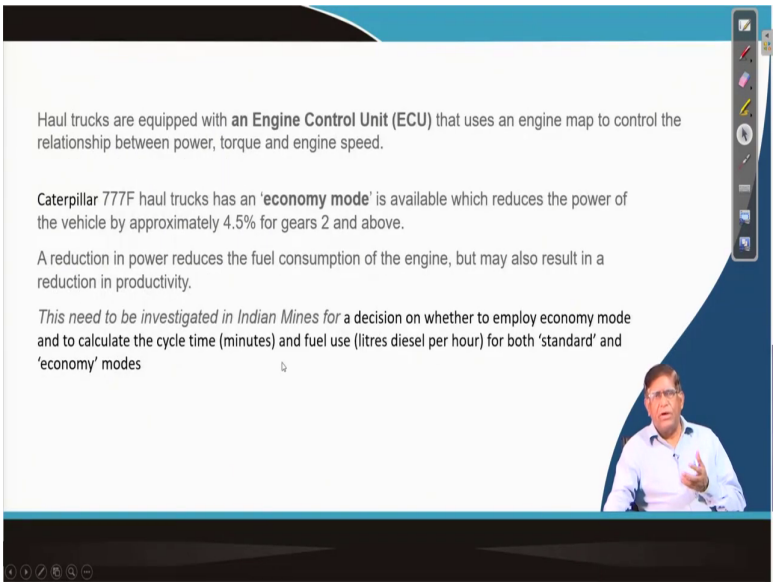

Now, haul trucks are equipped with here that energy control unit which exactly records, keep the records and then they are send it for analysis. So, this data which is very very important and then, whether the there is also provision in the modern trucks that we can put it in the economy mode and that whether a truck can operation in economy mode under a particular conditions, accordingly you can put that thing automatically economy mode to improve this ones.

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So, that is your how much time the truck is operating with which mode say that means, travelling empty, loading that you are stopped during for loading, travelling loaded and stop loaded, these conditions how much time, it has taken. This overall scenario will be affecting the total performance and energy consumptions.

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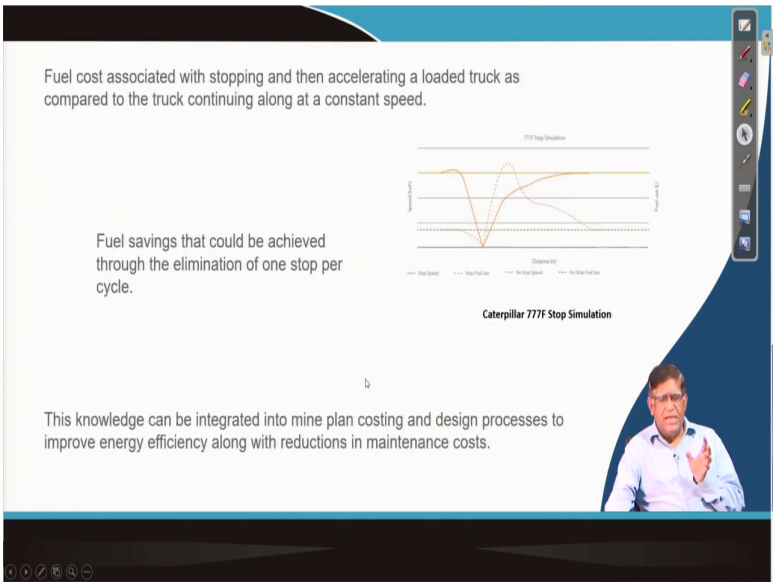

Similarly, the most important things you should see that during the hauling with a load, it should not get stopped; but the stopping may be necessary because of the traffic, sometimes something is coming in front that the your haul truck that is loaded truck is to stop. So, to avoid accident.

If your haul road design has not taken into consideration that their haul hauling will be there without stop, then this situation may come over here. Say for example, when your speed is stopped; it is running at a thing and then it is stopped over here and then again, it will get an acceleration time and it will go.

Now, during this stopping and accelerating, you can see that fuel consumptions which was going like that, as soon as it has stopped your fuel consumption has come over here and then this when your accelerating, at that time, the fuel consumption is higher and then before

coming it to the normal that when it goes to the steady state, then again the fuel consumption is coming over here.

Now, you see if this top were not there at that time, your these should have been that your fuel consumption line. But because of this one stop came, you can see that the fuel consumptions increased up to this much area under this curve is an increase in the fuel consumptions.

So, these shows that while you are going to improve the performance in terms of fuel consumptions that stoppages of the full loaded truck need to be reduced. So, this type of analysis can be done in while you will have to inspect your mine and there the mining layout can improved.

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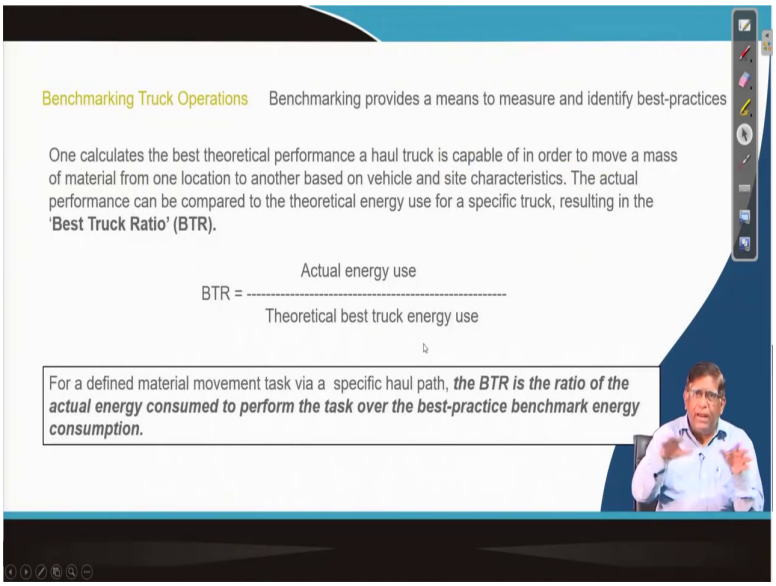

Similarly, the best if you know that what is the theoretically best truck energy use if you find that one and then, actually energy use what it is going on, this gives what is called your best truck ratio.

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Now, these best truck ratio, when you compare you can see here that is your your best truck ratio is a 2.55 for a payload of 126.21 tonne for a particular truck. In a case study, people have studied like this and you can see that the best truck ratio that with a payload even less. So, that means, that by just only having a higher truck itself will not give you the best performance.

See here this best truck ratio is less than this best truck ratio. So, that similarly if you will see that your truck selection using the that is your how the best truck ratio, they have which truck you will be selecting. Say here this truck is giving your that is your the different three models

of the truck have been taken 785C, 789C and 793C caterpillar these three trucks. Out of that, see this one is giving a higher best truck ratio best ratio; that means, this will be performing better.

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Similarly, this can be for that your how in the grade, it is working in this gradient you are working at this gradient working in these gradient. So, the gradient wise, your best truck ratio you are given when the grade 7 is there, in that you got the best truck ratio here 1 is to 7. Similarly, under the different conditions that is your in a rainy season or in a cloudy season, depending on that also you see that finding out the best truck ratio, you can identify where it will work.

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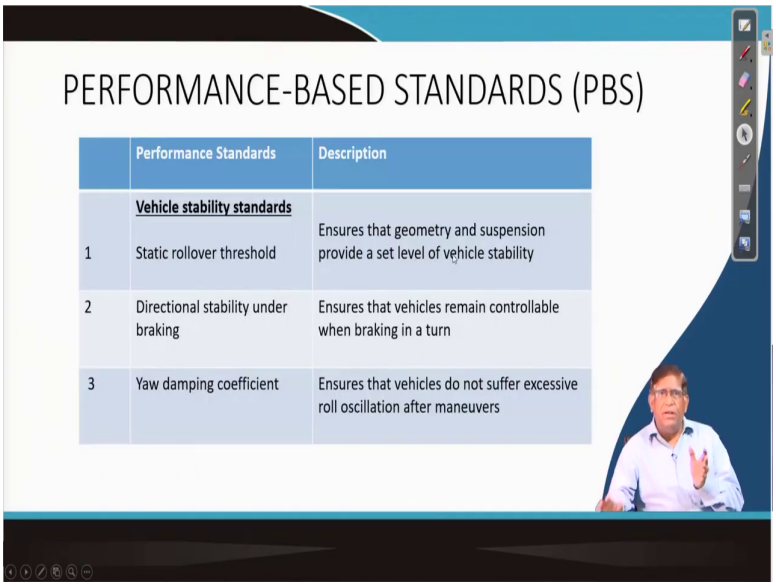

So, then another thing is their performance base standards. So, this is a these standards need to be find out you can take up some study at in our Indian mining conditions, we have to have study that what will be our perform based standard; how we can develop; how can you develop a best truck ratio for different haul road conditions that type of study has not been done much in our Indian mining scenario for selecting of different makes and different size of equipment for a particular shovel.

So, that is a research area, where we need to do some work. Similarly, that vehicle stability standard, we will have to have the vehicle say for example, you know that in a trucks, when it is moving with a heavy load and all. Particularly, you can see that if you are taking for coal that your body can be sized can be done because it can take more volume, now, when you are taking a more volume, whether the center of gravity will be changing.

Is there any yaw that you know yaw is when it is a there is a movement above the center of gravity, if it is taking over their if a truck yaw or there it can be a have a changing of a roll over; that means, whether a truck can fell down, when it is going down or going on an gradient or taking a turn.

So, those type of things are coming and you need to study that how it is stability of that equipment so that the geometry and suspension provide set level of the vehicle stability. So, in which way that the total dimensions of the truck and your the dimensions of the haul road, where it will be working, they will have to be compatible to this.

So, similarly your when you do the breaking, at the time of the stability should not get. If you are going in a very high speed, put a brake may vehicle may skid; sometime it may roll over as you can see in some of the light vehicles like trucks, cars. So, this is what exactly. So, that how the yaw damping coefficient means.

So, that it is does not go to a skid or does not roll over. So, for that the design of the truck need to take some measure. So, this type of performance-based standards need to be developed.

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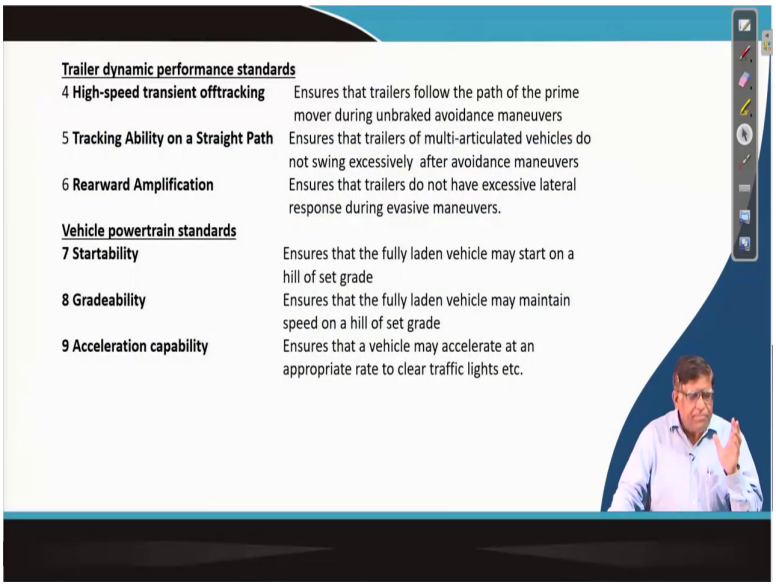

So, there will be trailer dynamic performance standards. Sometimes you use articulated truck. When you are using articulated truck, that the trailer which you are connecting. So, they will have to take certain measurement. So, your high speed transient off tracking that is your trailers follow the part of the prime mover, that is your that main that engine and that which is prime mover which is taking the trailer away, they will have to follow the same alignment and do while we are doing.

But at the same time, maneuvering and your negotiating curves that will have to be properly performed well. So, design part and your operating part need to be comfortable, that is your tracking ability of the straight path and rearward amplifications. Then, your vehicle powertrain standards that startability, gradeability and acceleration capability, these are the

things need to be studied with that equipment that it should be properly, then only we can say that is your performance is ensured.

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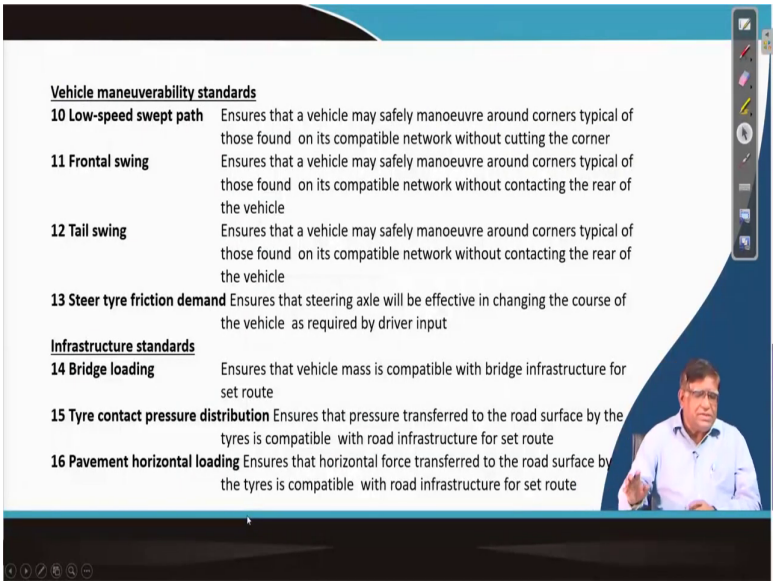

Similarly, maneuverability standards also need to be seen. In the mines what type of locations you are getting, in the phase your space all the thing are there or not. So, if you are taking a articulated bottom, this as dump truck taking to a phase. So, whether the backsides, how it will be swing, when you are doing at that is your turning within a short turning radius you want to do, how it will behave that need to be taken take care of.

Similarly, that is your when you are doing the steering, at that time how the tires are exactly interacting with the ground, those things will be also affecting the overall performance and overall cost. So, that is again while your haul roads that what type of road you are getting, if

there is a the that your tire they are getting shrunk, if it is their penetration is more on the road, there will be different.

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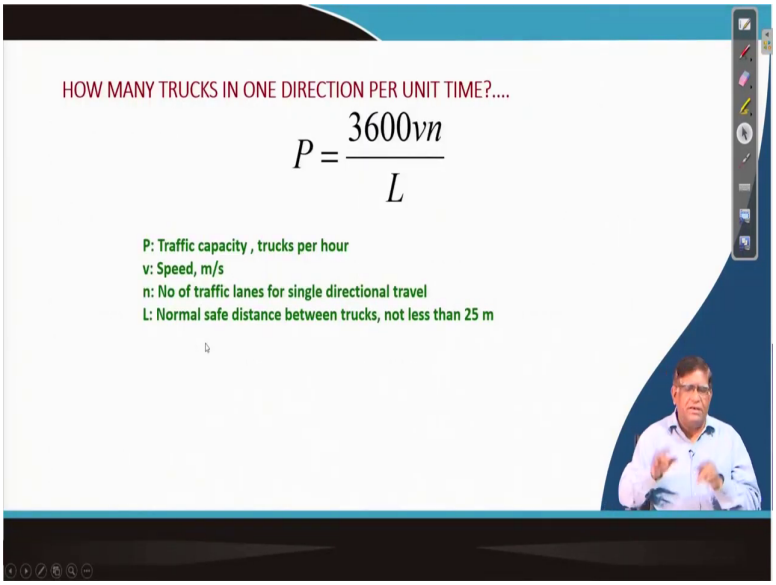

So, that is why the whole overall your road infrastructures which have been developed in the mines that will also affect. So, this way some performance-based standards are determined. Other things which you need to know is how many trucks in one direction per unit time. You can calculate it from the speed and the number of traffic lengths which you are having and the normal shape distance between trucks, how will you have to find.

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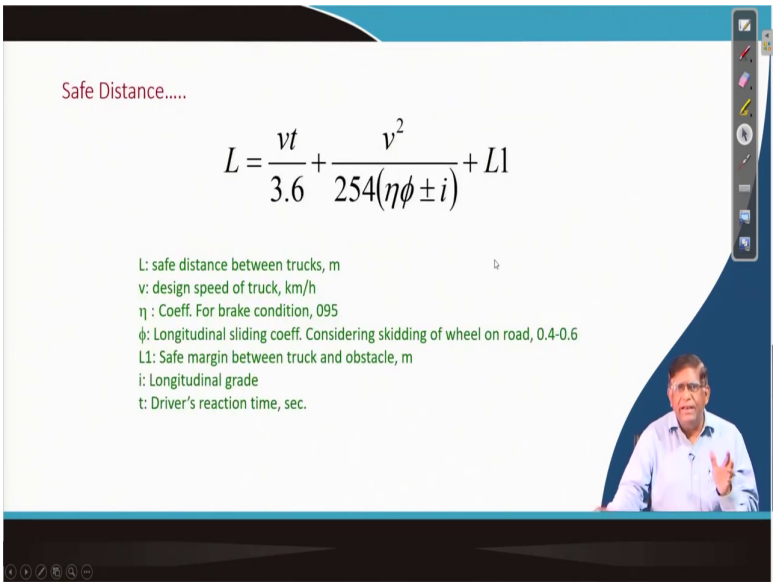

So, this is the way you can calculate this. Similarly, that what should be the safe distance between two trucks and then, what should be when you are brake at that time, where it should stop. So, that can be calculated from the equipment that is your you will have to maintain this safe distance between trucks, depending on your design speed.

And then, your coefficient of brake conditions, then longitudinal sliding coefficient, then safe margin between two trucks and the obstacle. If there is a something is there, how at what distance it must stop, so that L1 distance also effect.

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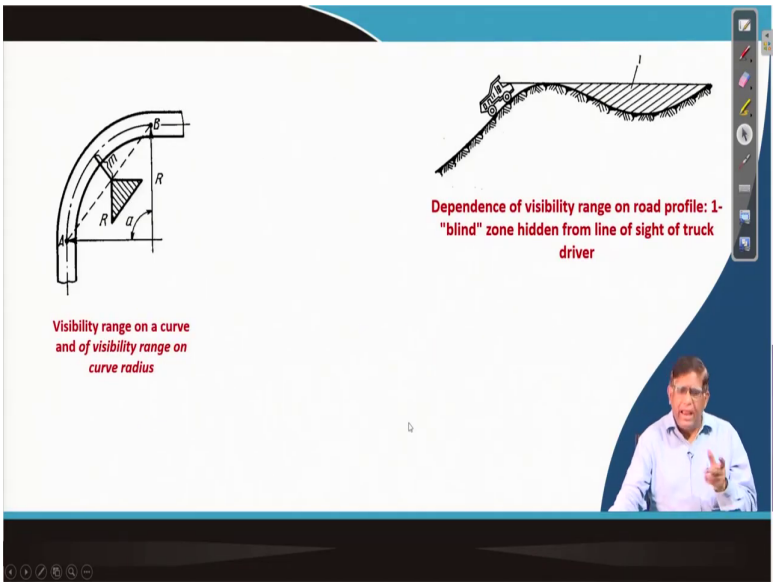

So, this is the way how we can derive these equations and calculate we need to do it. Because while doing it, you will have to see that what is the safe distance that will have to be there in the mine. If a this type of situations comes so that there will not be a vision that is a you cannot see the other truck, if it is coming over here.

So, there should be proper that is your alarming and things like that which nowadays that many new your electronic and digital gadgets are coming up to help the operator to see that in such type of situations, accident do not take place.

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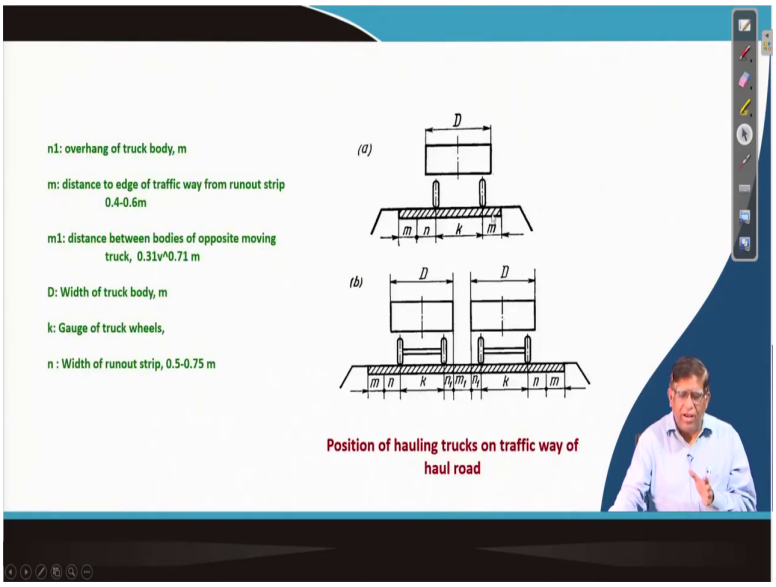

So, then you will have to see that truck, how it will be exactly maintaining your the truck body on a haul road, when it will be making how that two trucks will be having at how much distance. All these things are as a normal standard procedure are given; you will have to put; then, only you can achieve the proper performance of the truck.

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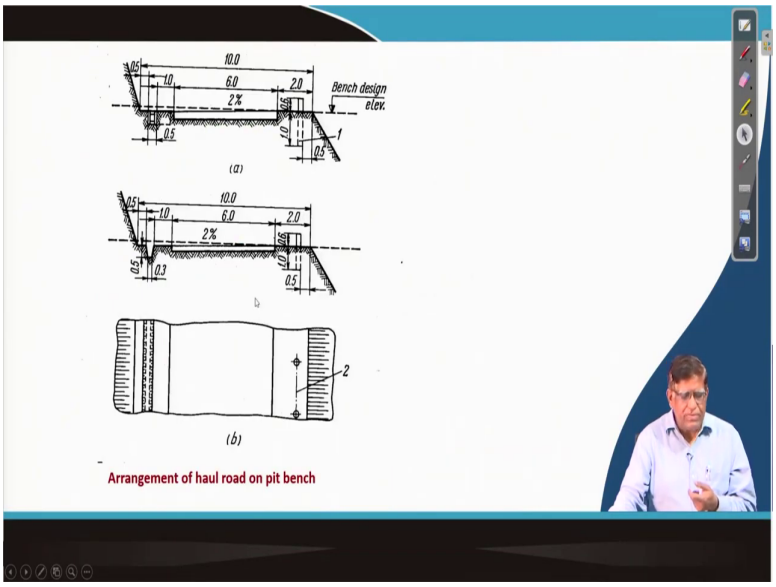

So, that means, the haul roads design that is whether there will be a proper gradient, there will be safety bomb and this you do in surface mining, when you do a haul road design. So, that means, for the performance of the truck, these two things should be comfortable that how will be deploying the truck on a things.

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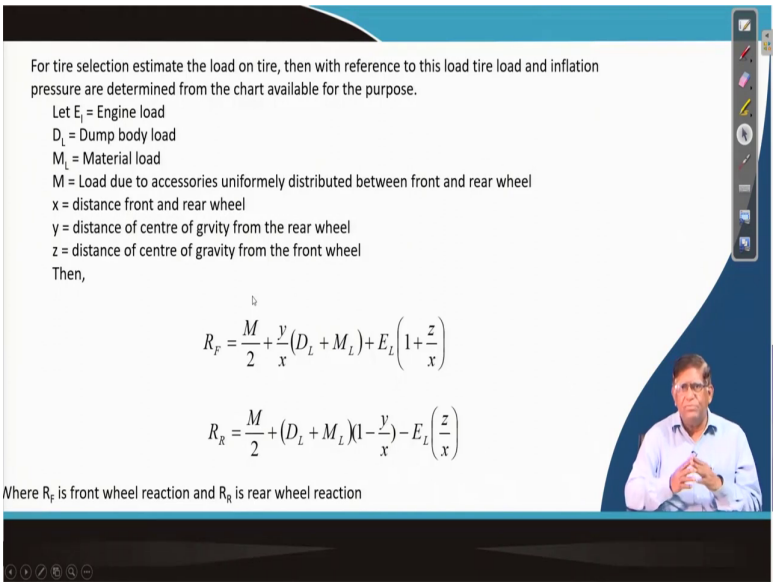

Similarly, another things you must know that a truck overall truck load that will be that is how much reactions will be coming in the front wheel and the rear wheel. These will be depending on the total load and that accessories which is coming over here and the distance between the front and rear wheel, that is the what is the length curve.

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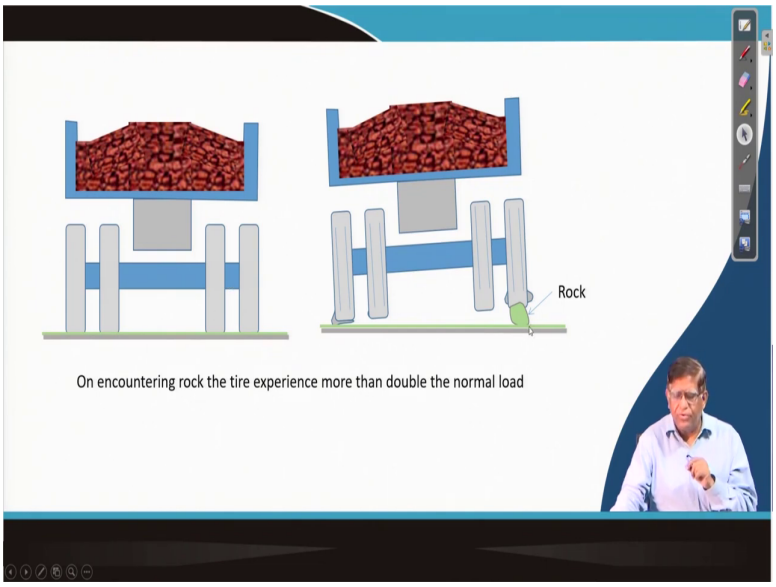

So, this way when you determine, this that normal reactions which come, it is important because the total load which is coming, it should get distributed to all tires equally. If now on the road a rock comes over here, then what will happen? The whole load will be coming onto one tire that will be getting over and this tire will get damaged and it will be loss.

So, that is why we need to know that by putting only if you are riding on a truck, then your how the total performance of the overall economy and everything will get jeopardize. So, that is why we need to know that how much load it may come.

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And then, another thing is that while you have to avoid in your field, particularly do not drive through water exactly such type of situations, you should not avoid, you should not do it over there. Then, you should not corner too fast say that means, if you are going in the corner, you are just touching it over here, this whole side of your tire will get damaged in the corner if you do fast.

Similarly, do not drive on the windrows. Say for example, here some spillage were there and windrow is formed on the road. Now, this truck is going over here. When you will be going on that windrow, that one truck will be riding on a rock and then, you will be see their unbalance load on different tires and this will be leading to the more tire wear.

So, similarly, if you do not let that is your tires if it is riding such type of rock is there, it will also give a damage to the tire. Similarly, that is your if there is any spillage or anything on the

road, it should be reported properly. Sometimes this type of while loading also a truck may get that is a differential loading will be coming to the different wheels that is also to be avoided.

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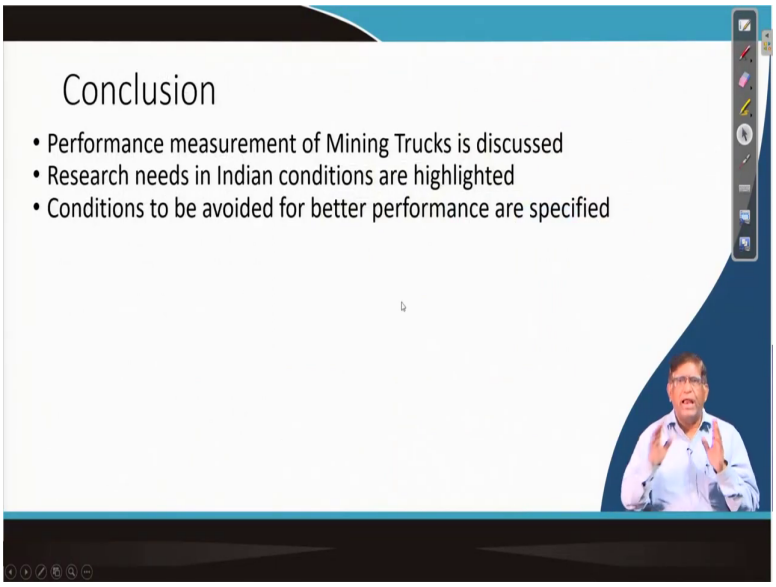

So, the operational practice also can lead to a very good performance. So, performance measurement in a mining truck is discussed today. You should know that this is exactly need to be a field-oriented study is required and then, site specific prescriptions come for the performance. Because mining at two places are always different. The equipment is designed with the best to give the best result under the given conditions and that conditions tuning up will have to be done over here.

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So, we should always take these things and a scientifically analyze the cause and the this effects of different situations. A lot of research have been done on this area. Here are some of the references, I have given you. But this is how we conclude on the discussions on dump truck, though there are lot of things are there to study on the trucks each and every component could be a matter of research.

So, I hope that you have got an idea about the mining truck and with this, we conclude our this module of discussions on mining trucks.

Thank you very much.