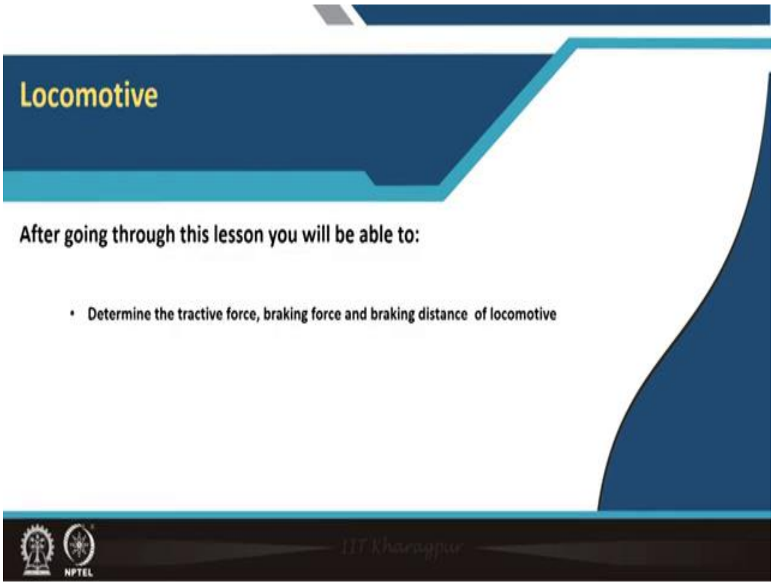
Bulk Material Transport and Handling System
Prof. Khanindra Pathak
Department of Mining Engineering
Indian Institute of Technology – Kharagpur

Lecture – 51
Locomotive

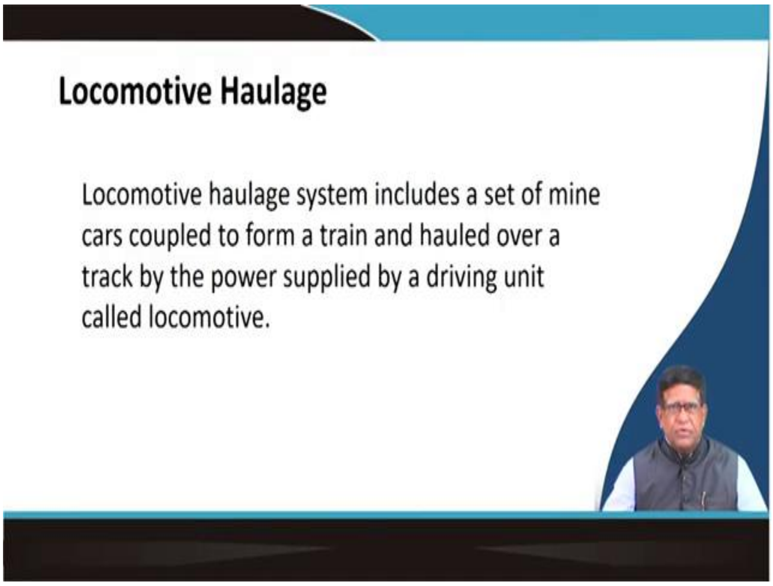
We have been discussing about the mine transport that is in underground mines, different mode of transportations, out of which we have discussed some of them and another mode of transportation is the your locomotive. So, locomotives are, as you know, you have seen Indian Railway that locomotives are well known to all of you.

(Refer Slide Time: 00:40)



But when you are talking about underground mine transport, they are of a smaller capacity. They have got a different constraints under which they work but the basic principles are the same. So, today you will be knowing about this. What are the basic principles of this locomotive. So that you can determine the tractive force, braking force or the braking distance. How to calculate that thing? As well as some general idea about this locomotive will be discussed today.

(Refer Slide Time: 01:14)

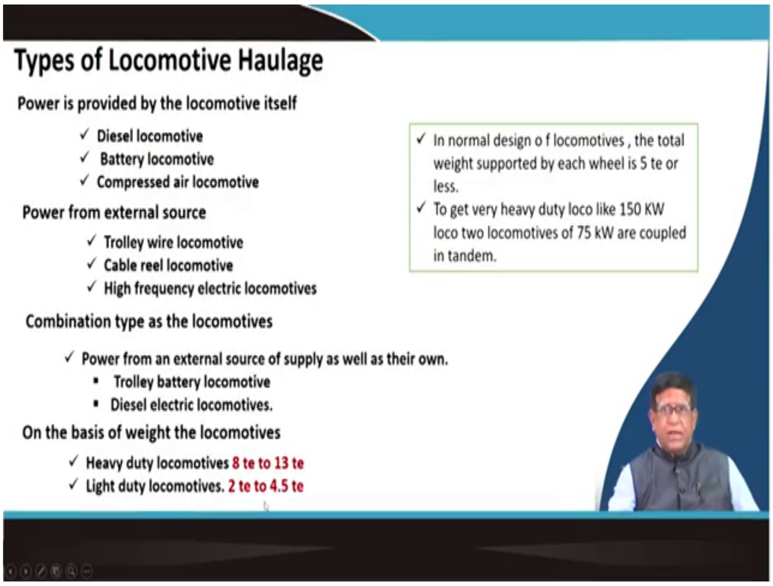


So, now this, as such, what is the meaning of locomotive haulage? It is locomotive haulage system includes a set of mine cars coupled to form a train. Just like a train you have seen there are number of wagons or this compartments in your Indian Railway. You have seen they are coupled that in between that same way, in underground mines, also, you have got the mine, cars or mine tubs.

That is which are normally only on two axles and 4 wheels. Those mine cars are coupled together, they form a train and then it is hauled on a track. And that hauling is done by the locomotive, whether it could be a self powered that is, it could be having an engine with the provision of say powering it like a diesel engine or it could be an electric motor. But there could be the driving unit, the main force it can be externally.

There are the pneumatic that is compressor pneumatic that compressed air driven locomotive. There are trolley assisted. That means they will be taking the power from an electric line and they will be carrying only the material. So, this locomotive is basically a train being hauled by a local engine.

(Refer Slide Time: 02:39)



So, if you see that there are different types of locomotive, haulage systems are there. When it is powered is provided by the locomotive itself. That is the train is having its own power which could be by diesel locomotive, battery locomotive or compressed air locomotive. These 3 are very commonly used in underground mines. Then there are power from external sources. There is trolley wire locomotive, just like your trolley assisted dump truck.

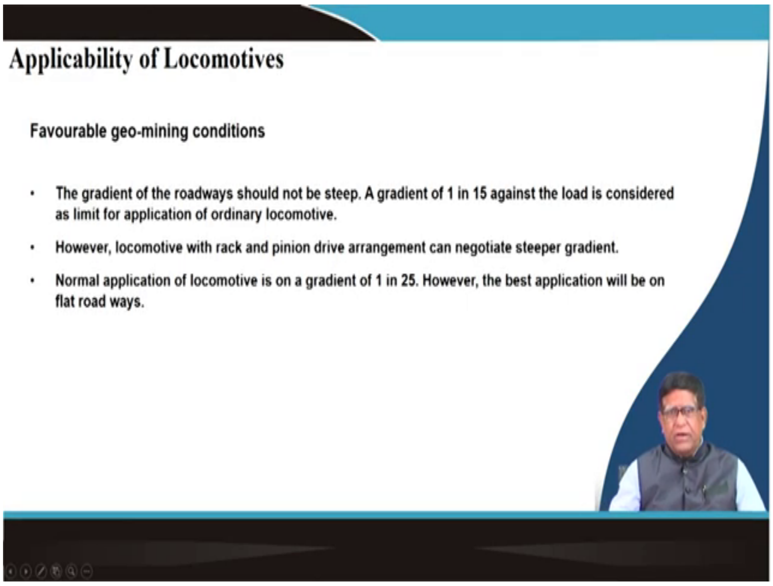
We have discussed earlier a trolley where locomotives are also there. Cable reel locomotive, there is a you are having a electric cable, where the power is given over there and then that through a limited distance that it will get when it is coming closer to that wheel, it will be this wound and then it will be while going. It will be unwinding by this both way rotating systems. A cable reel locomotives are also there.

Then high frequency electric locomotives are also there. Then the combination of these different types of locomotives. That is a you can have the power from external source supply as well as you have got its own also. That trolley battery locomotive, you have got a in the locomotive battery and also when there is a more resistance in gradient and all, you can get a trolley where supported.

And diesel electric locomotive is similar to your electro haul that trolley assisted dump truck type. That is your the locomotive is having a diesel. But where there is required, additional power is required it can derive from that external power line. Now, locomotives are also classified on the basis of their duty. That is your heavy duty or the light duty. Normally, you can see that underground mines, you may be having 2 to 3 tonne type of very small locomotives or you may have 8 to 10 tonne.

But where you were talking about this, our railway Indian Railway locomotives there are very, very super heavy duty locomotives. So, in the normal design of locomotives, the total weight supported each wheel is 5 tonne or less and then got very heavy duty 150 kilowatt locomotive or 75 kilometer low quad also, they can be two locos can be in tandem and they can be used depending on the power.

(Refer Slide Time: 05:19)



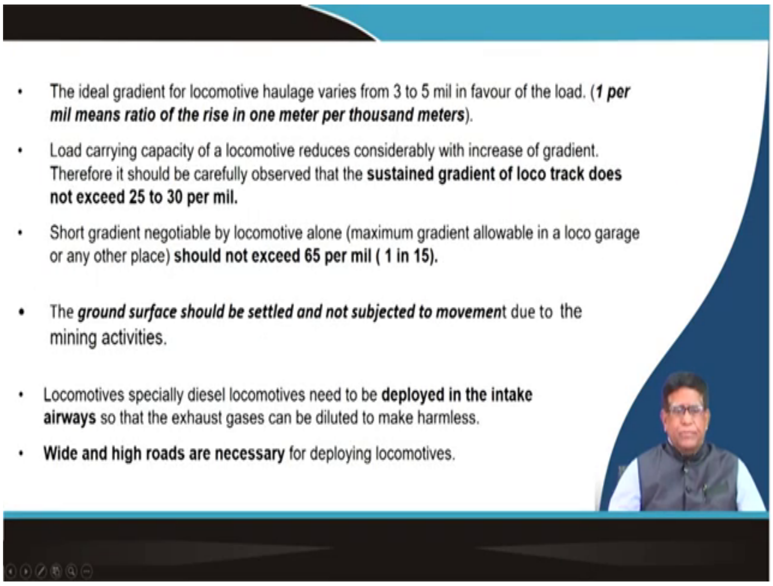
So, now the second thing which you need to know about where this locomotive will be applicable, in a underground mining the geo mining conditions that exactly dictate whether you can use it or not. The gradient of the roadways should not be steep. This locomotive it is not for that very high incline it cannot work. A gradient 1 in 15 against a load is considered as a limit.

If this it cannot work on a gradient higher than this then locomotive can be used with rack and pinion drive. That means the locomotive will be there when it is going up and then a double loop that is a you may have a chain conveyor which the chain will be giving a grip and then it is pulling the things just like. As we said in the creeper in case of your that pit top layout, we talked about the creeper similar to that a rack and pinion can be there.

Already that is your at the below the locomotive there will be a pinion and on the track there will be a rack. And then when it is with its own power drive that pinion will be driven on the rock it will be in the on the rack it will be moving. So that it will not be falling down in the gradient. So that type of systems in many places this is there. And normal application of locomotive is on a gradient of 1 in 25.

However, the best application will be on flat root surfaces. So, in the mind, wherever there is a in a horizon when it is travelling in a that horizontally in one gallery there, it can be used.

(Refer Slide Time: 07:10)



So, it that is why it could be used in combination with other rope haulage, direct rope haulage can bring the material from a lower horizon to a particular horizon where the shaft is there. So, there the materials can be brought. The ideal gradient for locomotive varies from 3 to 5 mil, this unit that is one per mil means ratio of the rise in one meter per thousand meters that is 3 meter per thousand meter or 5 meter per thousand meter, these are exactly the ideal conditions.

The load carrying capacity of the locomotive reduces considerably with increase of gradient. Therefore, it should be carefully observed that the sustained gradient of loco tracks does not exceed 25 or 30 per mil. That means 25 meter in thousand meters or 30 meter to in thousand meters, not more than that. So that means one thing is there, your gradient is a very very important factor and a resistive factor because you will not be able to do.

Because if the gradient is more than your the locomotive will not be able to pull the material. The ground surface should be settled and not subjected to movement. This is another important thing that is your, as you have said, in ground, bearing pressure that is the if the that your the rail, where it will be mounted on that base, base should be strong and supportive. It there should not be any movement.

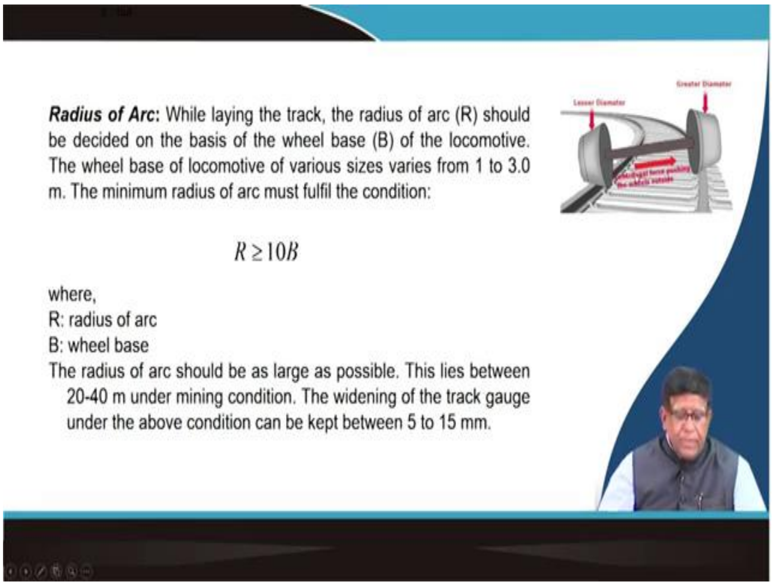
Now, sometimes that in underground mining it is a problem. We know two important problem that is, a critical problem is called floor heaving because that when the mine is opening up in a that is you are going down at that time this surface sometimes heave Because when you are taking out the material making a gallery at that time, the sidewise the pressure, the geotechnical pressure under the pressure because you have taken out the material there is a less pressure.

The pressure unbalance has taken place because of this pressure the floor sometimes may go heaving. That is called your floor heaving. If your geotechnical condition in the underground mine is subjected to having there. Your locomotive cannot be used because there will be derailment will take place. Then locomotive specially diesel locomotive when you are going to use in you will have to see about because diesel locomotive the diesel exhaust.

There are the gases which will be coming out it will be if they stay more in the underground it will be not good for the health of the miner. And also sometimes, if there is a the particles which may come out may be that say, you will have to have the diesel exhaust conditioner for controlling the temperature of the exhaust gases. But it should be always in the intake airways.

Because you will have to dilute that your exhaust gas concentrations in the ventilated air or in the atmosphere of the underground mines. So, another constraint or that or while you are going to apply, you will have to see that your mind design, it will have to be that is your gallery which will have to be more. These are the some of the issues that need to be considered when you are thinking of having this underground that locomotive you want to use.

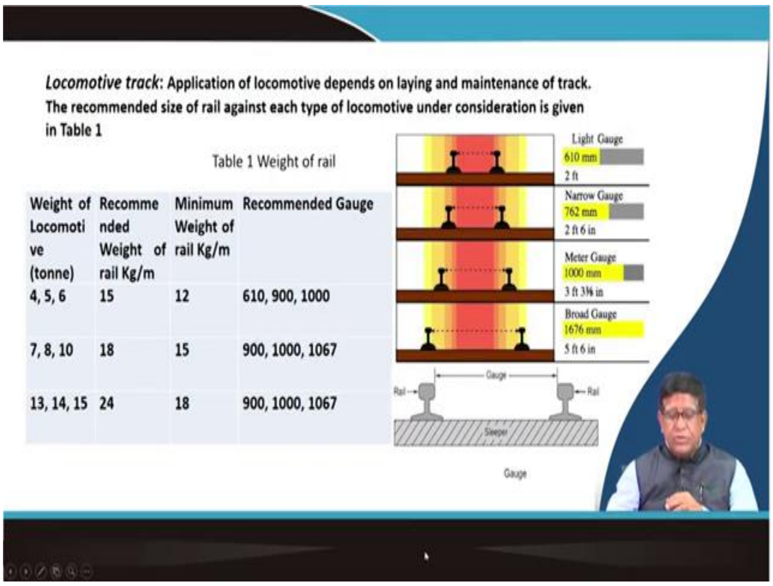
(Refer Slide Time: 10:49)



Now, there is another important point is this in underground you will have to sometimes have these curves, though, within the pillar you will have to make the curving is a very difficult situations also may come. Because when you are to take a turn, how you will do it? That arc that arc of curvature this is very very important. That is what is the radius of curvature of this arc will be, it will have to be very carefully designed and it is depending on the what is that wheel base?

Because at the time of turning your wheel, it will have to be on the track, if it is the your radius is short at that time what may happen your this may get a condition of derailment. So that condition which is given the radius should not be less than your 10 times the wheelbase this is normally followed.

(Refer Slide Time: 11:52)



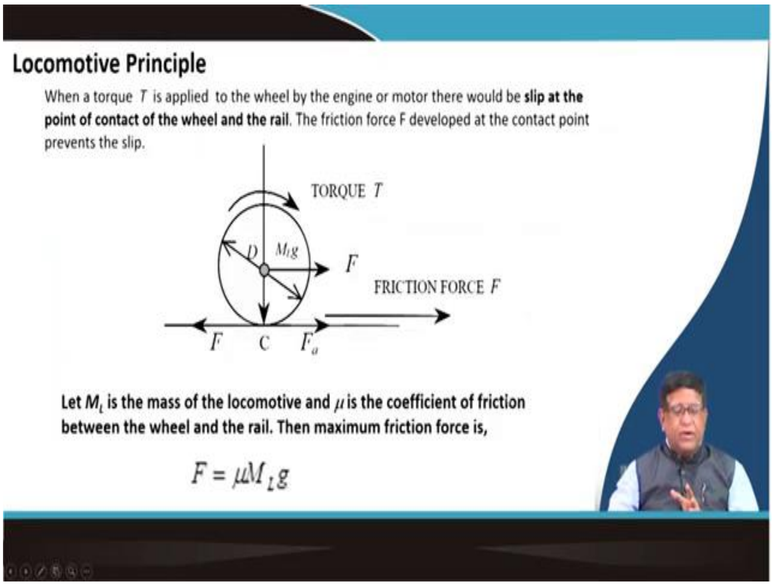
And that is why, whenever you are using a locomotive track the application it should be depending on that what is that wheelbase? And this your the rail which you will be using over here they will have to be also properly selected. Because the total weight of t will have to that rail of proper type will have to be selected if your the gauze, railway gauze. You know that is that the inner that this distance is called your railway gauze.

Now, this gauze, you might have heard about the meter gauze, narrow gauze, and light gauze. These are the dimensions that mean in our that broadcast which Indian Railway is having it is 1676 millimeter here. And then in narrow gauze sometimes in mines you will be finding light gauze 610 millimeter. If you are having such type of light gauze the rail which you will be having their specification, is only 15 kg per meter, a lighter one.

Now, you have to see that under there the length also because that when you are bringing this rail to the underground by the cage. That when the cage is going down from there, it will have to take a right angle that it will have to be from the case, it will have to taken out there. If you take a very long pole in the case then it will be difficult from there to take it away. So that is why there is the length of the rail is also selected.

Based on that what is the width dimension of the gallery and dimension of the cage? And that is why, in mines, you will be finding mostly the 610 millimeter narrow gauze. But in surface our locomotive in the Indian Railway. You will find this gauge where it is 24, even that high speed rail, you get 50, 60 that kg per meter special rails are also there. So, these informations are necessary for your general knowledge about how locomotives are being used in underground mine.

(Refer Slide Time: 14:00)



But the principle is now on that rail the wheel will be moving that in our previous class, also some in the mine cars we told about some of this where how the rails and that the track in the mine track. But these wheels when it will be rotating on the rails there are what are the different forces acting on it? So, this how much exactly the tractive force? That means how much force it will be there?

So that what is the that total weight of the train that can be pulled by a locomotive? That is a very important things to be known. Normally, what will feel that when a wheel is to be rotated on that there will be a normal force will be working on that the weight will be coming over here. And it is at the point of contact there is your the main friction will be working frictional force is there.

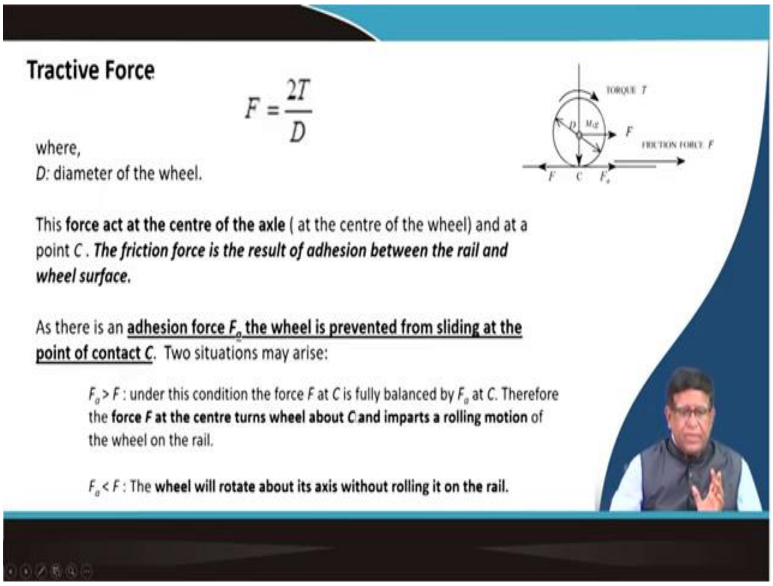
And also there is a adhesion between this two? That is the surfaces. There is a, this adhesive force is also there and then the axle of this wheel will be driven by that your whether it is a battery electric diesel, it will be giving a torque. So, now under the torque it will have to rotate. And then this, what is necessary, your wheel will have to roll. Now that is the total friction on the addition at this point C.

It will have to be such a condition that whatever the torque you will be applying if it is properly not selected or the proper power is not given. That it will be just that wheel will rotate but it will not roll. So, for that that when the torque T is applied to the wheel by the engine or motor there will be a slip at the point of contact of the wheel and drill. This at this point and the frictional force is developed.

Because wherever there is a relative motion there that there will be a friction and this frictions will be acting in this direction. Now, at this, if the total weight which is coming over here is M L and this coefficient of friction is mu then the total force because of the friction what will be coming over here is this mu M L g. That is very basic physics you have already learnt. Now, this in case of your while pulling a force pulling a box on a incline order that type of problem you have.

That this to move it this direction, your you will have to apply a force equal to that friction force. Then it will start moving at that point.

(Refer Slide Time: 17:11)

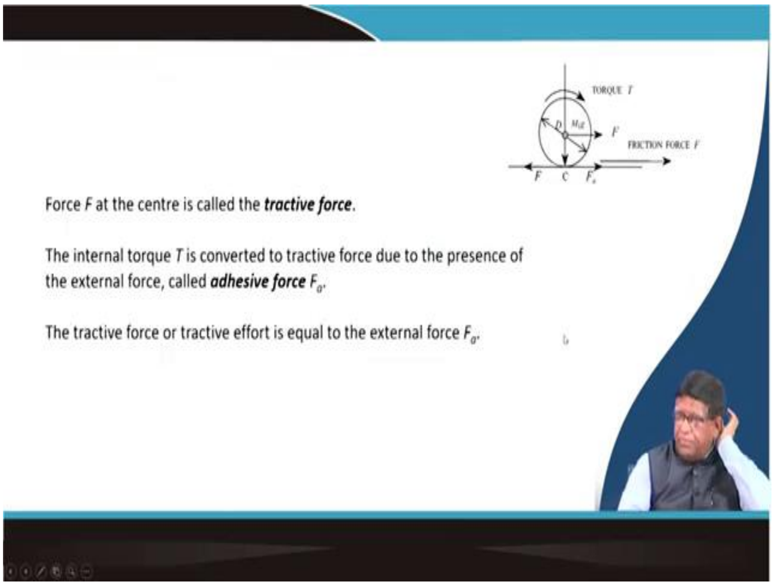


Now, the tractive force in case of to make this wheel to roll so that it can go. You will have to see that this torque because this force is there. So that torque it will have to create a couple that is your force into the radius. If your diameter is D that your this force, you can easily calculate it out, it will be your 2 T by D, D by 2 is the radius. So, you are finding out this force.

Now, this force will be acting at the center of the axle here and at the point C, so that they are forming this couple and this will now start rotating. Now, as there is an adhesion force between these wheel that will prevent it from sliding. Now because if there is no addition, it will start sliding at that point and when this adhesive force, how much is this adhesive force that will determine whether it will be just rolling or it will be just rotating on that surface?

This adhesive force which is there as a F a, if it is greater than your frictional force that condition that she is fully balanced this couple it will get fully balanced and therefore the force F at the center turns the wheel and it imparts a rolling motion. And if this F a is less than this F at that point, it will start just rotating over here. But it will not roll or the trolley will not go forward. So, this is the condition which you know from your basic, your higher secondary physics.

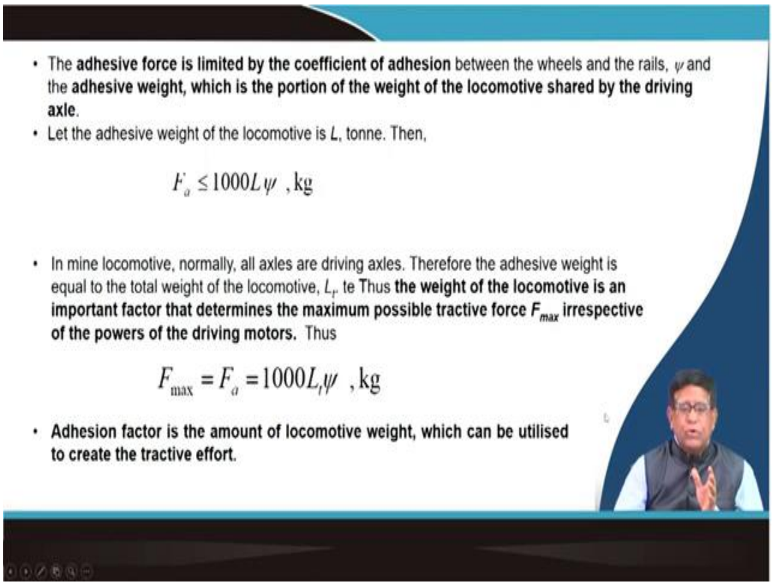
(Refer Slide Time: 19:01)



Now, this force at the center is called your tractive force. Now, when a locomotive is there that is at the back you are connecting the train that will have to be pulled by this force and then this internal torque T that is converted into destructive force. And that your this extending force that is your the adhesive force. Now, tractive force or the tractive effort is equal to this adhesive force which you are telling it over here.

So that means the coefficient of addition and coefficient of friction at the point of contact is very important for getting that whether your locomotive will be able to pull or not.

(Refer Slide Time: 19:55)



Now, the adhesive force is limited by the coefficient of adhesion between the wheels and the rails now, this is denoted by psi. That is when this coefficient of adhesion and the adhesive weight which is the portion of the weight of the locomotive shared by the driving actually. That total because the total weight it may be depending on your there are two excels mean at the 4th point supports.

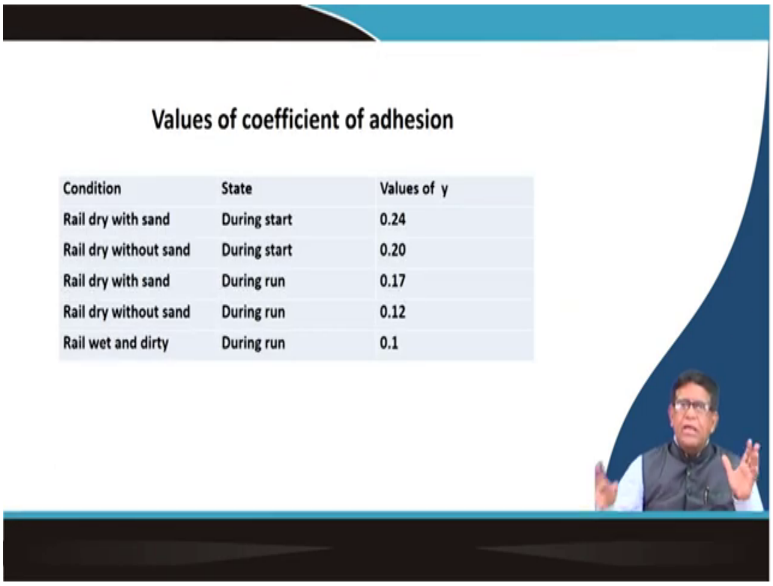
So, the total weight is connected coming onto one wheel is getting your one 4th of the total weight and that weight is important here. Let the adhesive weight of the locomotive is L. Then your this force will be that is which is L in tone. So that is thousand into this coefficient of addition this much is the adhesive force coming. Now, in a mine locomotive that all axles are driving axles.

You consider like that. Therefore, the adhesive weight is equal to the total weight of the locomotive. That is, the weight of the locomotive is an important factor that determines the maximum possible tractive force. That means that locomotive where the engine and all thing is there what is each weight? That means it is not that what is the power you are giving at the that your axle that is how much torque you are getting for that?

How much, how much exactly the motor is giving power that is not important but important is what is the total weight of that locomotive because that will be giving a factor for doing the tractive effort. This is important to note. Now, the weight of the locomotive is important factor that determines the maximum possible tractive force, irrespective of the powers of the driving motors.

Thus your that maximum force which will be available for your pulling the train, is your this adhesive force or this is your this particular one that it is adhesive weight which we are giving your equal to the tractive effort which you will be getting. Now, the adhesive addition factor is amount of locomotive weight which can be utilized to create the tractive effort. So, mainly the traction or the movement or the hauling action of the train will be coming with this coefficient of adhesion.

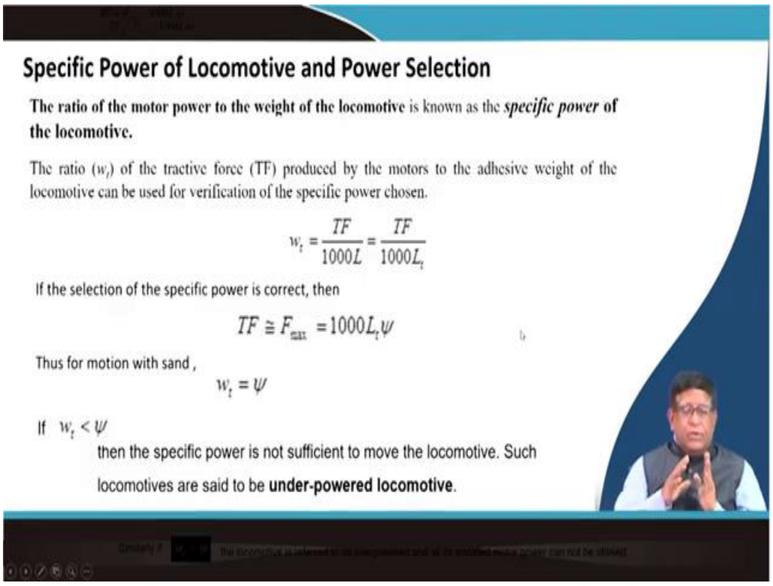
(Refer Slide Time: 22:27)



Now, depending on that what type of rail and then, what type of your conditions there your this coefficient of addition can be different? Now that you can find out that is from the different design books, sometimes the from the experiment, many researchers they design. It find it out that what will be this adhesive force it can be calculated. Now, the rail will dry with sand or the rail dry without sand.

That is you may be knowing that during the decision, if it is there in your, there is always a sandbox in the locomotive and while it is driving it put the sand on the rail so that this coefficient of addition that can be increased. So that is your weight and dirty your it goes 0.1. That means that whatever the weight of that your locomotive only 10 percent will be available for tractive effort. In case of dry it is 24 percent will be available for that pulling the train.

(Refer Slide Time: 23:41)



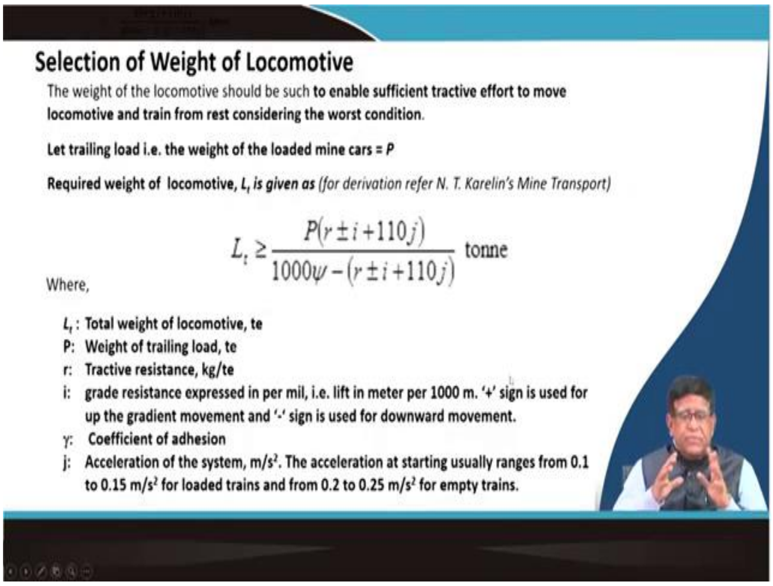
So, this another important point you need to know is a specific power of locomotive and how you select that power, the ratio of the motor power to the weight of the locomotive is known as the specific power of the locomotive. As we have said that is your the motor power it is exactly that how much that the locomotives weight that important. That is why the ratio is called specific power of the locomotive,

Because the locomotive on the basis of this power it will be able to draw or it will be moving the train. Now, the ratio which is of the tractive force produced by the motor to the adhesive weight of the locomotive, it is used for verification of the specific power. Now that is your tractive force is there and then your total weight is there. So that means tonne that means this is the kg tractive force in kg.

So, this ratio is important. Now, if you see that this one is also almost that means this yours, this ratio of this reactive force and that your power adjacent power it can be equivalent or it is equal to your adhesive coefficient of addition. Here also if this ratio is less than the coefficient of addition then, the specific power is not sufficient to move the locomotive. Such locomotives are said to be under power locomotive.

So, depending on that whenever you have to see you have to test that whatever the locomotive you are having. And then whatever your down the track condition under that condition, this locomotive will be able to draw or not.

(Refer Slide Time: 25:44)



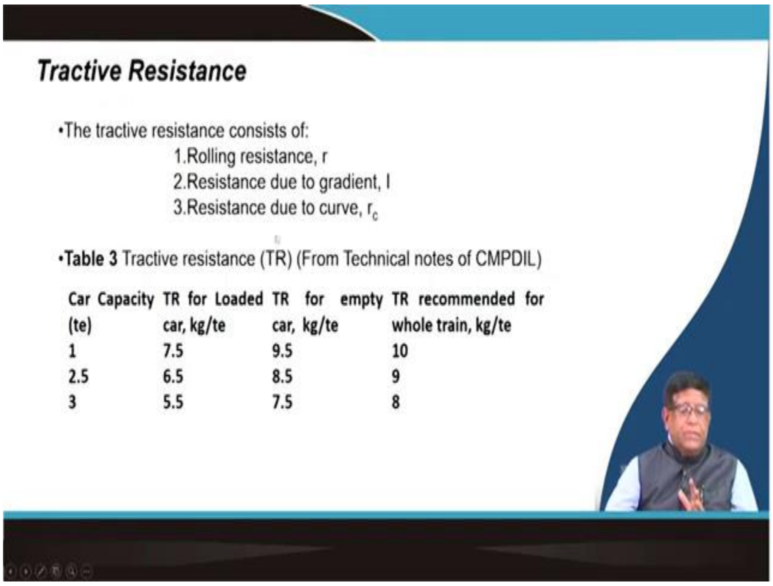
Now that weight of the locomotive that means for your working conditions for your number of cars and number of total weight that what will be that loco? How will you select? That means the locomotive manufacturer they can give you the right loco. So that you can take you are going to take in the underground mine from the phase to the shaft bottom. Maybe you want to take 10 tubs.

10 tubs means there will be the total weight will be say 30 tons or there could be 5 tubs only it can do. Because 15 tonne if you are taking 2 tonne of coal and 1 tonne or 1 tonne of coal and 2 tonne of the weight of the car. So, by knowing that you will have to select that what will be the locomotive? Because if you tell the specify the locomotive weight then the designer can design that locomotive that what type of motor or what type of drive it can be accommodated over there.

The weight of the locomotive should be enabled to sufficient tractive effort to move the locomotive train. And if your trailing load that is the total load of the mine cars in a train is P. Then this required locomotive weight can be calculated by considering the tractive resistance. That is your grade resistance and the acceleration at what acceleration you are going to give. Now, this formula derivation is there in the N. T. Karelin's book you can see.

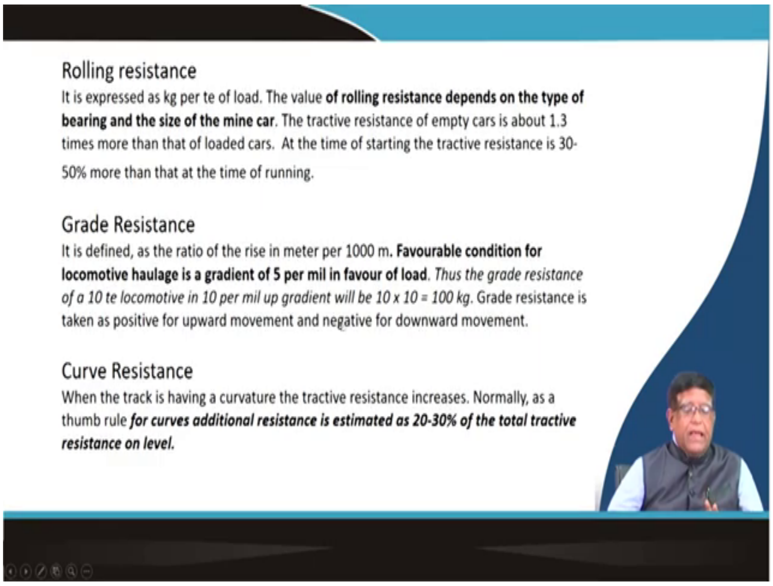
But right now you remember that it is that by this factor 110 is kept for this your acceleration and this gradient, if it is down the gradient, it will be minus if of the gradient it will be plus and then it is a coefficient of your addition is known from here you can calculate it out.

(Refer Slide Time: 27:41)



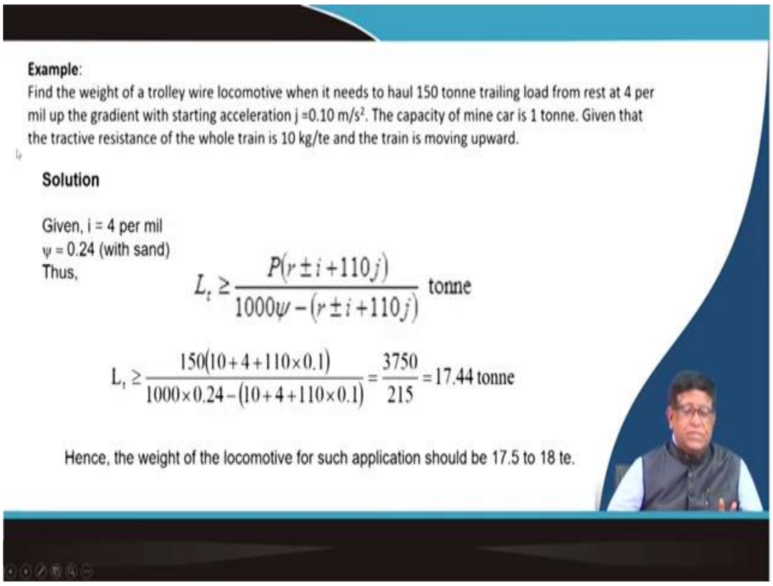
So, the tractive resistance is it will be consisting of that is basically the rolling resistance, your resistance due to gradient and then resistance due to the curve. That the what are the tractive resistances you can calculate even our CMPDIL that they use to give for the underground mine transport design that values are given over there which you need to select over here.

(Refer Slide Time: 28:07)



This rolling resistance, grade resistance and curve resistance combined their resistances will be the total resistance coming your that is your locomotive selection, will be based on this resistances.

(Refer Slide Time: 28:20)

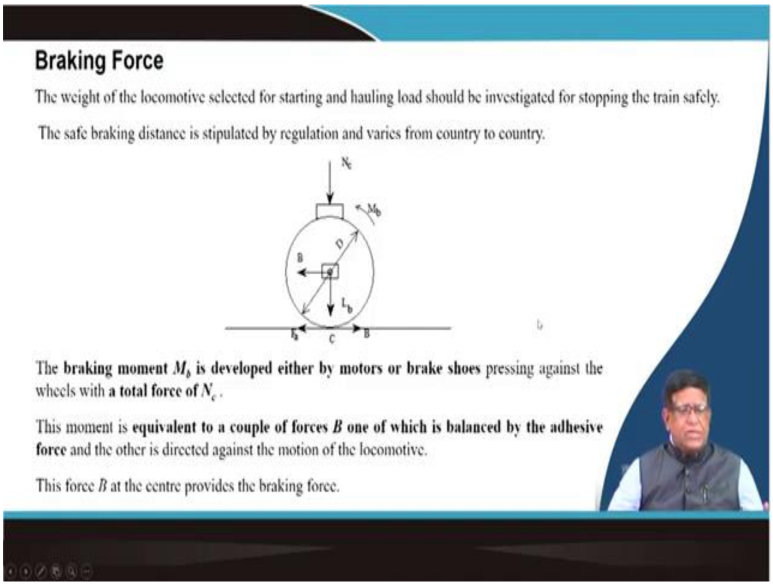


So, now you write down this problem, find the weight of a trolley where locomotive when it needs to haul 150 tonne trailing load that is the total load of the train from rest at 4 per mil up the gradient. That means 4 meter that is a gradient is 4 meter in thousand meters with starting acceleration, 0.1 meter per second square and the capacity of mine car is 1 tonne. Given that the tractive resistance of the whole train is 10 kg per tonne and the train is moving upward.

So, you can use this here it is given your i is 4 per mil and then your j is given 0.24. So, your this equations you can apply it over here and that will be giving your 17.44 tonne. Now that your weight of the locomotive it is given then you can find out once you find then you can see that what is the available in the market that locomotives there are locomotives available of 18 tonne.

So, you will be selecting 18 tonne that fractional it will not be coming over there if it is coming, say 16 or it is coming say 16.5 then also if the available in the market is 18 then you will be selecting the 18 tonnes. So, this type of basic calculations are necessary.

(Refer Slide Time: 29:52)

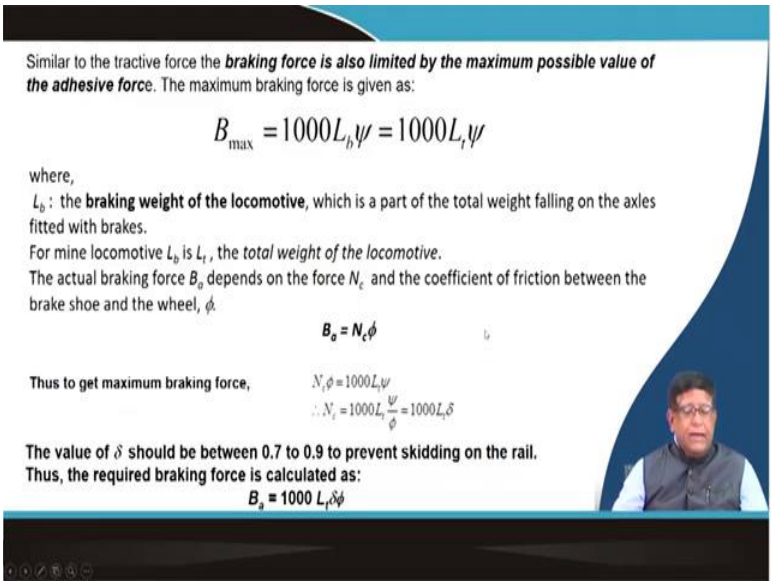


Now, the one thing is there if you are moving in a gradient and then your it is at sometimes you want to stop because some problem has come you will have to brake it. Now, applying the brake that means when it was rolling over here a opposite couple will have to be applied. Now, to apply this once that braking resistance or the braking force, how much it will be there?

It can be either the your you can give by the motor giving and applying a force in the opposite directions or you will have to apply a brake shoe which will be holding it over there so that it cannot move. So, this the braking movement that can be developed by motor or by the brake shoe and this moment is equivalent to a couple of force that is B. So, just like your tractive force, you are getting this F here in this diagram.

Now, this braking force B will have to be there it will be coming because of the torque M b is applied which can be applied by the motor or by the brake shoe.

(Refer Slide Time: 31:01)

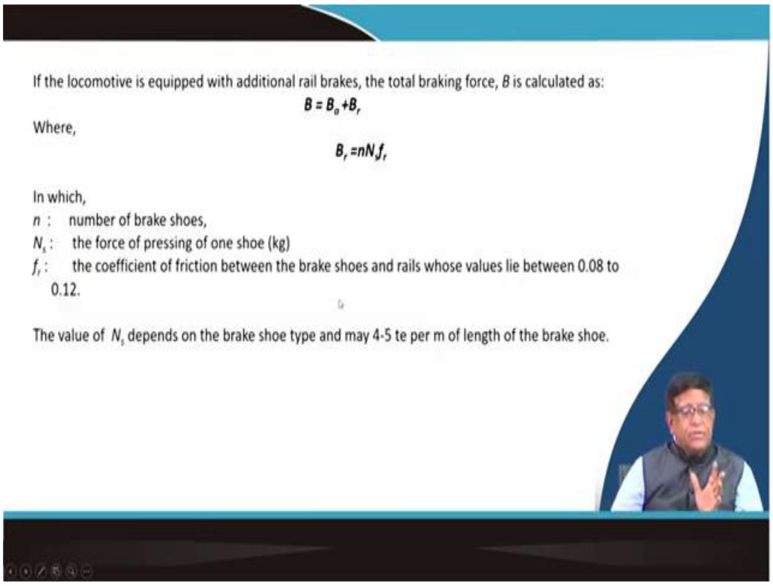


And this maximum one that is also by the similar logic and similar force argument. Your brake maximum braking force will be again, it will depend on the adhesive force. So, you can calculate it out. So that is why, once you know there is the braking weight of the locomotive which is a part of the total weight falling on the axial fitted with the brake. For mine locomotive, this braking load it is equal to the weight of the locomotive.

That is and the actual braking force depends on the this exactly that what is the total weight coming? This normal force depending on that your this braking force will be determined. And as a to get the maximum braking force. You can calculate out that this is the ratio of your the adhesive force and the frictional force. So which is this ratio is often till as delta and this value of delta should be between 0.7 to 0.9.

So that the rail will not exactly when you apply the brake then the rail should not skid on the rail. So that is why your braking force so that it does not skid you will have to calculate by this formula.

(Refer Slide Time: 32:25)

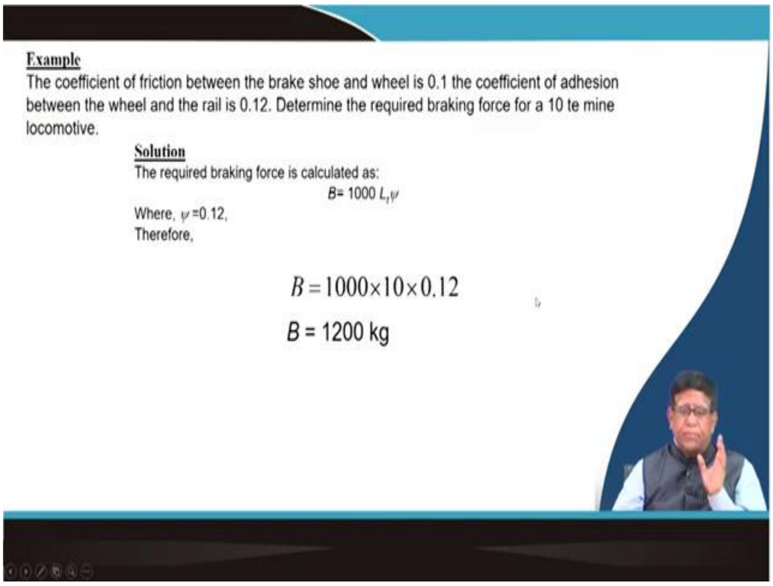


So, this way the locomotive is equipped with a additional rail brake that is total braking force can be. That is whatever your from the motor by applying that couple and then you give additional brake also can be given you apply it by brake shoes. That additional brake comes your exactly the number of brake through and then your total force which is coming over there that is the total force of one brake shoe.

Because there could be in the wheel brake shoe from two sides. It could be coming there are two wheels each of them will be having. So, 4 number of brake shoes can be applying the braking force. Now, the coefficient of friction, it is again depending on the system what you are doing, it will be value is 0.08 to 0.12. And that this number the force how many that what is the force coming over the braking shoe that will be depending on the what type of shoe?

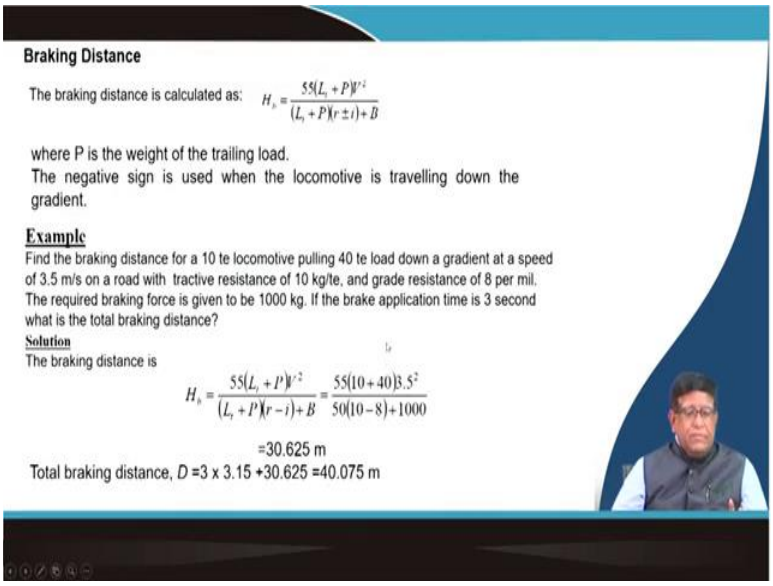
Whether you are having what type of rubber? What type of steel? And then their liner depending on that. It could be normally 4 to 5 tonne per meter length of the brake shoe.

(Refer Slide Time: 33:38)



That is, you use this film for information. Then you can calculate if the coefficient of friction between the brake shoe and the wheel is given 0.1, the coefficient of addition between the wheel and the rail is given 0.12. Then determine the required braking force. It is a simple application of the formula and you can find out what is your braking force.

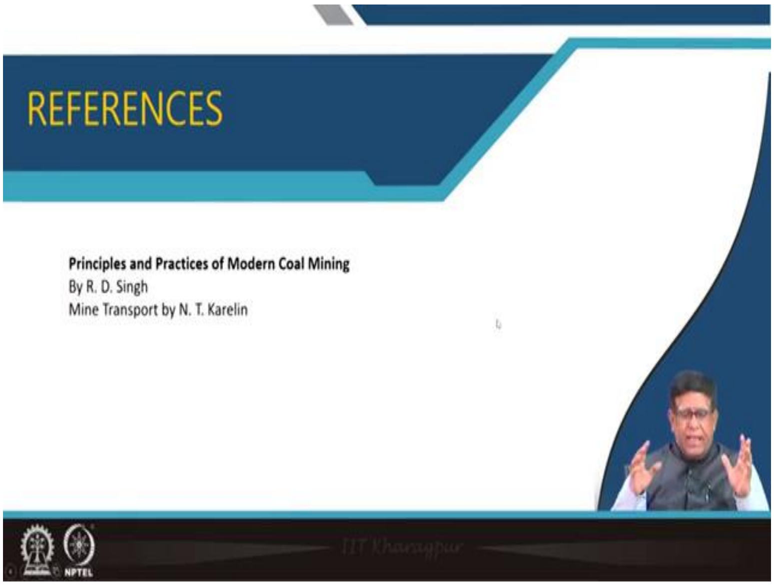
(Refer Slide Time: 33:59)



So, this braking distance it is calculated by this formula and this also the derivation you can see in textbook by Karelin. And that your the weight, whether your P is the weight of the trailing load and then your B is at what velocity it is moving. So, you can do a problem like this find a braking distance for a tent on locomotive pulling 40 tonne load down the gradient at a speed of 3.5 meter per second on a road with tractive resistance 10 kg per tonne.

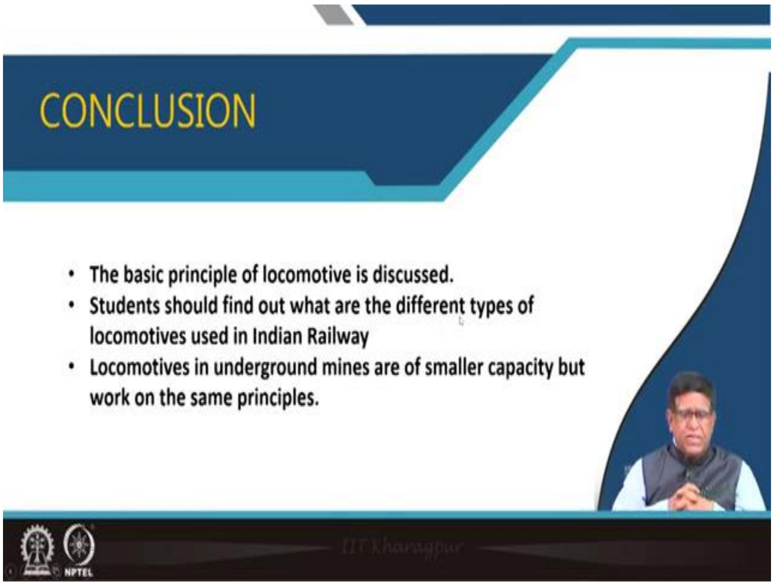
The gradient resistance of 8 per mil. The required braking force is given to be 1000 kg. If the brake application time is 3 second, what is the total braking distance? By just simple application of this formula you can calculate this. That means it will have to be at 40 meter. This type of calculations will be very much necessary while managing the mines for safety. So, designing the braking distance then you will have to see whether the atmosphere is there or not. Lot of other factors comes into consideration in the real designing.

(Refer Slide Time: 35:14)



So, I request you: you can read these two books. That is your by R. D. Singh's Principle and Practice of Modern Coal Mining and Mine Transport by N. T. Karelin. There the derivations of this are there.

(Refer Slide Time: 35:31)



So, you can do a little bit of exercise the basic principle only we have discussed and you should find out that different types of locomotive used in Indian Railway, though we are telling it in underground mines. You know that Indian underground mine is only very limited number of mines are there. But the Indian Railway is a first railway and the locomotives are of very different type.

If someone of you go for that transportation engineering there the railway transportation engineering is a very vast subject. There is a center of railway research, even at IIT Kharagpur. And there are that the quite a large number of engineers are working in Indian Railway Engineering Services through Indian Railway Engineering Services. If, after graduations, you is to join in the Transportation Engineering in Indian Railway Locomotives will be your things and there how high power engines are used?

How these are maintained? That is an area where you should have an interest and should prepare for appearing the Indian Railway Services Examination and aspire for becoming a Transportation Engineer railway engineer in Indian Railway. Thank you very much.