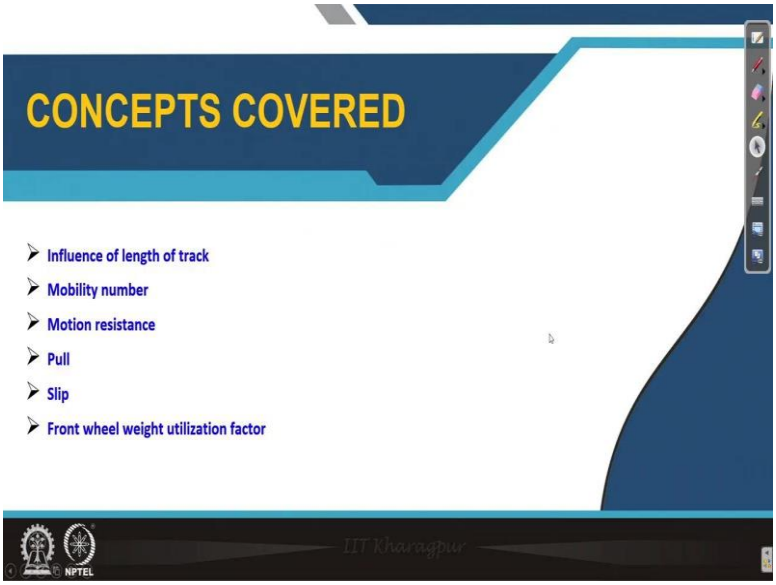
Traction Engineering
Professor Hifjur Raheman
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur
Lecture 25
Tutorial 5 -Influence of Track Length on Performance of a Walking tractor and Selection of Suitable Size of Tyre for a Given Size of Tractor.

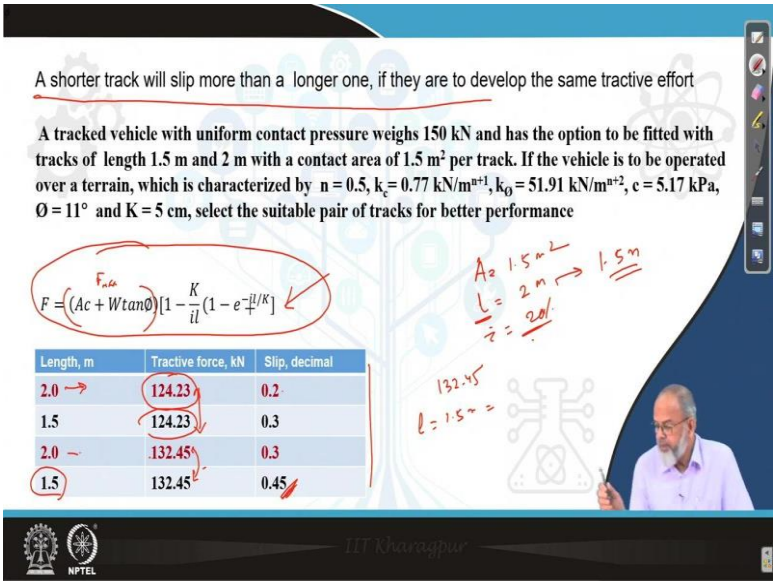
Hi everyone, this is professor H. Raheman from Agricultural and Food Engineering Department, IIT Kharagpur. I welcome you all to this NPTEL course on traction engineering. This is a tutorial class where I will try to cover how the length of track is influencing the performance of a walking tractor? And then we will try to discuss about selection of a suitable tyre size for a given size of tractor.

(Refer Slide Time: 1:03)



So, first these are the parameters which will be utilised for deciding the influence of track length on its performance and some of these parameters are also responsible for selecting the tyre. So, that is listed all these parameters, which will be utilised in those 2 problems which I am going to solve.

(Refer Slide Time: 1:26)



The problem is very short in the sense statement. I have given, a shorter track will slip more than a longer one, if they are to develop the same tractive effort. This is the statement. We have to justify this statement. So, in other words, what we are doing is, we are trying to say that if a track is having longer length, it will always develop better tractive performance. That means, it will develop more tractive effort. So, to prove that, you have to take one example: a tracked vehicle with uniform contact pressure whose weight is given and it has the option to be fitted with say tracks of different length, starting from 1.5 meter then we have changed to 2 meter and the contact area of each track because the vehicle will have 2 tracks, so, each track contract area is given. If the vehicle is to be operated over a terrain that has been characterized by an exponent of sinkage n whose value is 0.5 and coefficient modulus of sinkage 0.77 kN/m^{n+1}. Then frictional modulus of sinkage is 51.91 kN/m^{n+2}, then cohesion 5.17 kPa, angle of internal friction ϕ as 11° and shear deformation modulus K is 5 centimeter.

So, under these conditions, we have to select a suitable pair of tracks. That means, the track which is giving better tractive performance that will be selected. So, since the question is, the longer ones should be higher tractive effort, so, the equation which is related to tractive force for a loose sand and the weight, assuming the weight of the track is uniformly distributed over the ground. So, the question is F = Ac+Wtanϕ. So, this is maximum thrust. So, this is your maximum thrust developed. This bracket portion and this is the portion, which is, portion is due to the variation of slip and length.

So,

So,

$$F = (Ac + W tan\varphi)\left[1 - \frac{K}{il}(1 - e^{-\frac{il}{K}})\right]$$

i is the slip, l is the length of the track. The rest of the things are same for both the soil. If we look at the first bracketed term, W is also same whether it is a small track or the bigger track. W is kept same and contact area is also same.

So, this is the governing equation based on which we have to find out what will be the, which one will be giving the better tractive performance. So, what I have done is, have taken 2-meter length as a track for one track, then I tried to find out at 20 per cent slip, what is the tractive force which is developed utilizing this equation.

Because all the values are given 'A' I have taken as 1.5 meter square and length of track I have taken us 2 meter and slip I have taken as 20 per cent. So, what we observed here is, we are getting a tractive force of 124.23 kilo Newton. Now, I changed the length to 1.5 meter and what we observed is a tractive effort which is lesser then what is observed in case of 2 meter length. So, what I did is, I varied the percent, a slip percentage from 20 to 30 per cent then what I observed is, the tractive effort is matching with the tractive effort which is developed in case of 2 meter track. But slip is different.

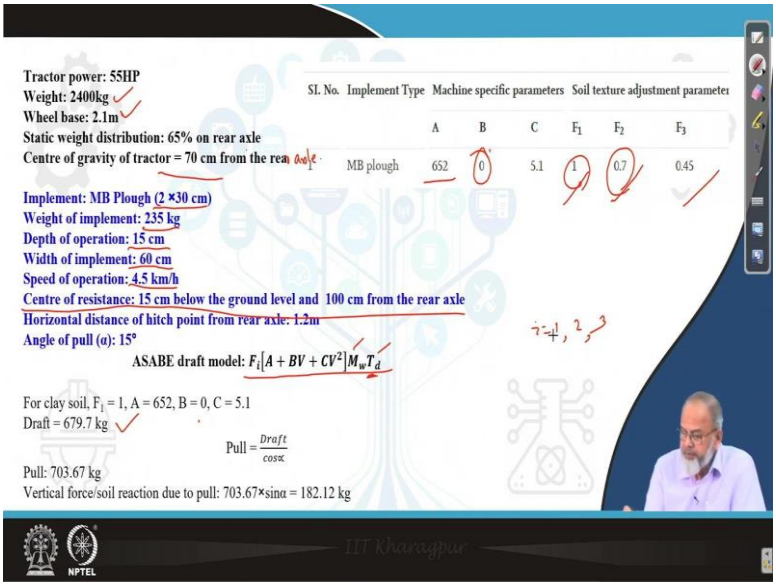
So, again we tried at another slip value for a 2 meter track length. I changed the slip to 30 per cent. So, I got a value of tractive force as 132.45. Now, to get that tractive force, again I tried with a 1.5 meter length, that means I change l to 1.5 meter and what I observed is, when the slip is 0.45 that means 45 per cent, then only we are developing a tractive effort, which is equal to the tractive effort developed by a 2 meter length track. So, from these 2 observations, what we can conclude is, it is the length of the track which is giving you more tractive effort for the same slip.

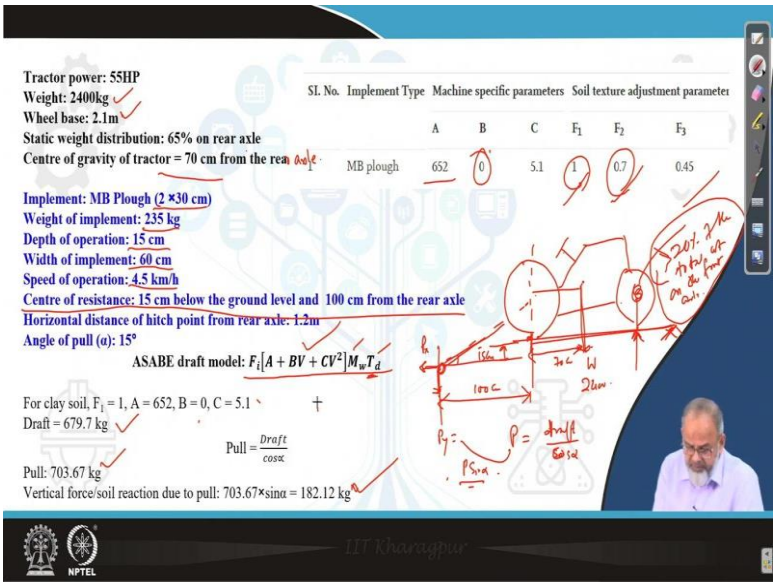
Now, the statement which I said, a shorter track has to slip more than the longer one. So, if we look at these, to get the same tractive effort, the 2 meter track length slips only 20 percent whereas, the 1.5-meter track length, it slips 30 percent. So, the statement is proved. To further check this one, if you look at 2 meter length, at 30 percent slip you are getting 132.45 kilo Newtons tractive effort. To get the same tractive effort of 132.45 kilo Newton the shorter track, that means 1.5-meter length track has to slip by 45 percent to develop the same tractive effort.

So, the statement which is given like a shorter track which is more, is now justified from this example. So, basically it is the governing equation that has to be remembered and then we need to know how to utilise this equation by the parameters like soil parameters and weight coming on the track and the contact area of the track and different slip values, then only you can calculate.

So, the next thing is, a problem which will be dealing with the selection of tires. For example, someone wants to have a tractor particular size say 55 hp. If the company people who fit the tyres and that is there you cannot change it because they will say this is the best one. But if you really want to analyze which one is best one, then you have to do this exercise.

(Refer Slide Time: 8:48)





So, we have to select a tractor tyre for 55 hp tractor. So, what are, the information we required? We required to know what is the total weight, what is the wheelbase, what is the static weight distribution. This is important, how much weight is coming in the rear axle and how much weight is coming in the front axle? That is important.

So, just for convenience, I have indicated that yes, in the rear axle it is 65 percent and obviously in the front axle it is the rest 35 percent. Then the other important component is, what is the location of CG, how far it is from the rear axle, CG from the rear axle, distance of CG from the rear axle? Then question arises, what kind of implement you are going to select?

So, we want that the tractor should give you maximum power. So, maximum power means, it is the tillage operations which will give you maximum power. Tillage operation again, the primary tillage operations related to deeper tillage. for in our case, mouldboard plough is the implement which is going to give you the maximum draft and it is a clay soil which will give you the maximum draft force.

So, we want to know the details about the implement whether it is a 2-bottom mouldboard plough or whether is the 3 bottom mouldboard plough. Once you select the plough, then what should be the number of bottoms, then what is the total weight of the implement that means mouldboard plough, then what depth you want to operate, what is the width, then at what speed you are going to operate? These are some of the information which you require, then the most important thing is the center of resistance, how far it is away from the center of the rear axle, and how much below the ground level?

If this information are available and the angle of pull is available, then we will try to find out, what is the weight transfer or what is the dynamic weight coming at the rear axle and what is the dynamic weight coming on the front axle? So, before that, once you decided the implement and knowing different information, the next step is how to calculate the draft? ASABE equation is the only equation which will give you draft computation. So, the ASABE draft equation is given as this

$$Draft\ (D) = F_i[A + B \times V + C \times V^2]M_w T_d$$

Where, M_w is the width, T_d is the depth and V is the forward speed, A, B, C are parameters which value are listed here.

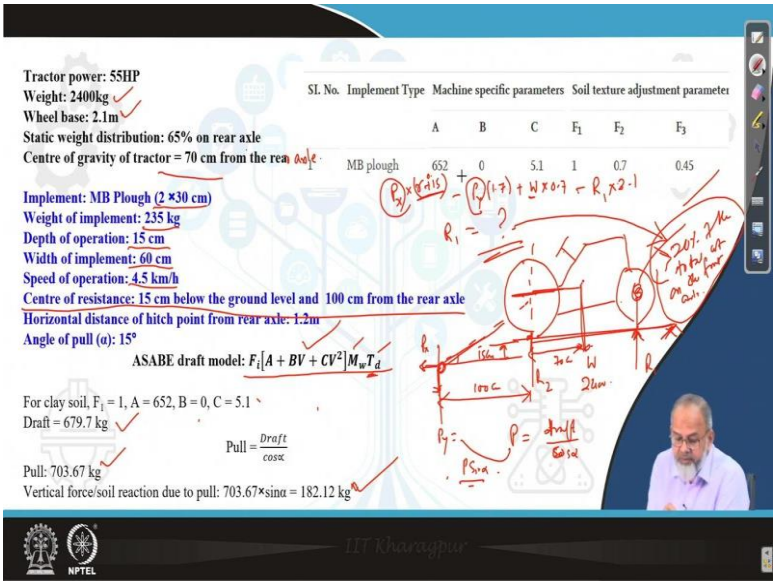
For MB plough, have already decided from that ASABE standard what are the values of A, B and C. Value of A is 652, value of B is 0 and value of C is 5.1 and F_1, F_2, F_3 these are soil texture adjustment parameters, Fi 1 means F_1, means i could be 1, it could be 2, it could be 3. If it is 1 then the value is, Fi value is 1, if it is F_2 then the Fi is 0.7, if it is F_3 the Fi value is 0.45. So, basically it is the hardness of soil. In that way if I have to take, for clay soil, we have decided these are the parameters 1 F_1 value is 1, A value 652, B value is 0 and C value is 5.1. Then we try to find out what is the value at a forward speed of 4.5 km/h and at a depth of 15 centimeters. This is the draft value which is found out. Then what will be the pull? So, pull will be, if I draw a tractor here so, this is the ground, so, pull will be somewhere here, this is the line of pull and what I am saying is, the line of pull is making certain angle with the horizontal and the center of resistance is say, distance away from the rear axle and the center of gravity is also at the distance from the rear axle. This is your central gravity W and you need to know the total weight.

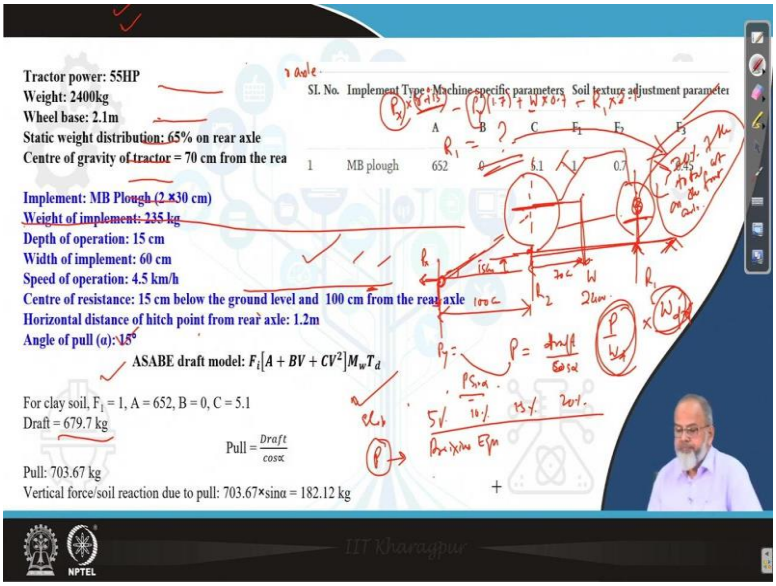
So, in our case we have taken 'W' as 2400 kg. So, this distance is to be known and it is given 70 centimeter and this distance center of resistance is 100 centimeter from the rear axle and this is the ground, this is 15 centimeter and 15 centimeters below the ground level. So, there will be a reaction at the front wheel, there will be the reaction at the rear wheel. So, this pull(P), I can resolve into 2 components P_x which is nothing but your draft which I have already calculated using the ASABE equation and the vertical component is your P_y.

So, that $P = D/\cos\alpha$. So, that will give you a pull(P) and from P we calculate P_y which is nothing but $P \times \sin\alpha$. So, that way we got 182.12 kg. So, we got the value of draft, we got the value of pull, we got the value of vertical component P_y. The next thing is, you have to find out what is the dynamic weight coming in the front axle because we need to steer the vehicle comfortably during operation.

So, for steering the vehicle comfortably, we need to have at least 20 percent of the total weight on the front axle. So, we have to now find out, what is the dynamic weight coming on the front axle and then verify whether this condition is satisfied or not? So, for calculating the dynamic weight we have to take a moment about the center of the rear axle around the central axis of the rear axle. So, now, these are the 2 forces, then this is the total weight acting, this is the front wheel reaction.

(Refer Slide Time: 16:39)





Since you are taking moment about this line, so, what we are getting is, $P_x \times (r+15)$. If you want to make it in meter, 0.15 meter. Then moment because of y it will be minus. So, moment because of P_y will be $P_y \times (1+0.7)$. Now, W, this is positive clockwise. So, moment due to W is $W \times 0.7 - R_1 \times 2.1$. So, if the P_x value is nothing but the draft, P_y value is this value. So, if W value is known, so, if you substitute this one from here, we can find out what is the value of R1.

So, now, you will verify this condition, whatever value is coming whether it is giving us this condition satisfied or not. If not, that means, if not, we have to reject the case. That means, the tractor is not, the tyre which is fitted is not suitable, we have to put some more weight at the front. So, rolling resistance will increase. So, that means this tyre diameter is taking a role here.

So, you have taken R plus 15 so, tyre diameter is taking a role. So, this exercise after you finish, what is the dynamic weight?

The next thing is, the pull which is developed by the tractor. So far, we have not calculated. So, you have to now calculate how much is the pull that should be greater than or equal to the draft value which is required to pull the implement. So, for finding out the pull which is developed, we can take the help of Brixius equation. So, that means, you have to calculate the mobility number then at different slip values starting from 5 percent, 10 percent, 15 percent, we have to find out what is the pull which is developed. It cannot exceed beyond 20 percent or maximum range should be a maximum range of slip should be within 20 percent. So, at different values of slips 5 percent, 10 percent, 15 percent and 20 percent, we have to find out what is the pull which is developed using Brixius equation. Brixius equation gives you tractive effort the torque ratio, so torque ratio minus rolling motion resistance ratio. So, that will give you the coefficient of traction and coefficient of traction if you multiply the dynamic weight so, that will give you the what is the pull which is developed.

So, let me repeat again, for calculating pull there is no direct equation given by Brixius. We have to find out the torque ratio first, then find out the rolling resistance ratio or the motion resistance ratio and the difference of these 2 will give you the coefficient of traction or coefficient of net traction. So, which is nothing but P upon dynamic weight of the dynamic weight coming on the wheel or axle. Now, you multiply it whatever value you are getting just multiply with the dynamic weight.

So, dynamic weight of the front axle we have calculated just now, similar exercise you have to carry out at this line centerline of the front wheel that means, you need to know the tyre diameter which is provided at the front. So, we find out dynamic weight of the front axle, dynamic of the rear axle. Since it is a 2-wheel tractor, so, this has to be multiply with the dynamic weight on the rear axle. So, that will give you what is the pull which could be developed by a tractor and that should be greater than this draft requirement of the implement. So, that is the third condition which has to be satisfied.

The first condition is the steering ability, second condition is the draft should match, third condition is the slip should be within 20 percent. If these conditions are satisfied, then only we can say this tyre which is selected is good enough to carry out this tillage operations. So, the possibilities there could be many tyres available in the market like 13.6-28, 16.9-28. So, it may

happen that both the tyre will satisfy this condition, all these 3 conditions are satisfied by both the tyres for pulling a 2-bottom mouldboard plough.

So, what you have to do is, if you really want to know here the pulling ability of the tractor, then you can increase the number of bottom of mouldboard plough that is one possibility and then carry out the same exercise and see whether these 3 conditions are satisfied or not. If not one of them is not satisfied that means that tyre is not suitable. Suppose in the worst case that both the tyres which I mentioned may satisfy the 3 conditions for increasing the number of bottoms of mouldboard plough then comes the cost factor there as a fourth component.

So, if both the tyres are suitable, then go for finding out which one is economical. Economical means, where I have to pay less to purchase the tyre. So, obviously, the smaller size will cost less. So, you have to select the smaller size tyre. So, these are the procedure which has to be followed for selecting a tyre. That means, initially you have to calculate for the maximum draft requiring implement, how much draft is required, then we finally find out what is the pull or draft which is developed by the tractor using Brixius equation, then we find out what is the dynamic weight which is coming, I mean dynamic weight is required before calculating the Brixius number.

So, in the second step, the dynamic weight calculation for the front as well as the rear wheel are to be done. In the third case you have to find out the pull developed by the tractor under different slip conditions. Maximum we can go up to 20 percent. And once these are calculated that means the pull which is developed is within 20 percent and it is satisfying the draft requirement that the implement, and the second thing is what is the steering ability that means, the weight on the front axle should be more than the 20 percent of the total weight.

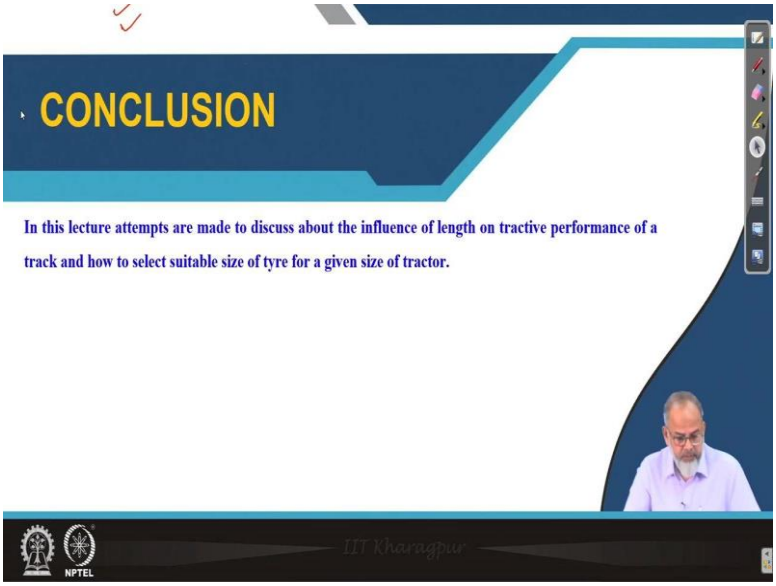
So, these conditions are to be satisfied. If these conditions are satisfied for say x number of tyres. So, then question is, which tyre is giving you less cost that means, what is the purchase price of these tyres. The tyres have a lesser purchase price you can select. So, I hope this will give you some idea. So, only difficulty here is, the ASABE equation. Now, the ASABE equation says that draft values which are predicted is plus or minus 50 percent. So, since we do not have any good predictive equations available to estimate the draft, so, that is why you are relying on the ASABE equation.

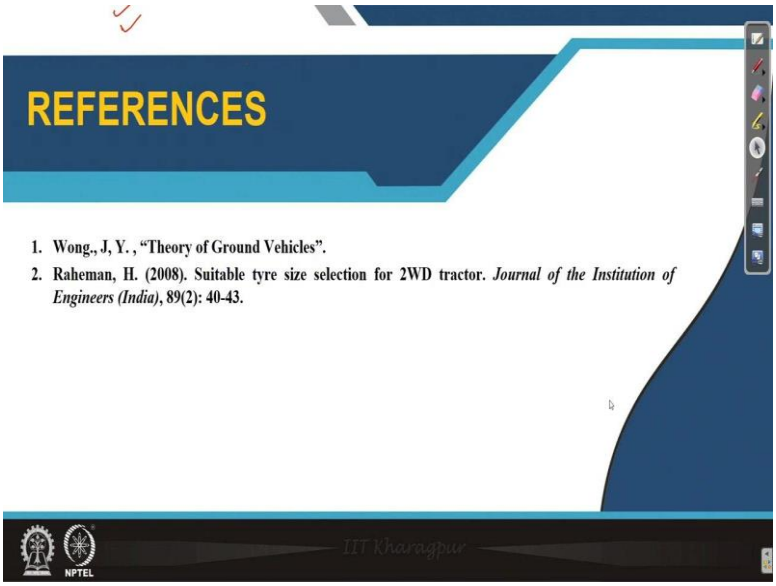
Otherwise, the procedure is simple. So, what we can do is a program can be developed by which by giving the information like the tractor specifications CG distance will base then

statics weight distribution. If those informations are given then implement informations are given and the soil conditions are given then immediately it will calculate all these parameters which I mentioned like draft, pull, the draft deployed by the tractor, then whether the condition is satisfied, whether this draft which is of the pull is developed by the tractor is within 20 percent or not.

Then next is, what is the dynamic weight coming in the front axle, if that condition that is, it should be more than 20 percent all the time, 20 percent of the total weight. If these conditions are satisfied then immediately the program will say okay this is the output, output means this tyre is suitable that becomes easier task.

(Refer Slide Time: 26:37)





So, basically, I attempted to calculate the influence of the, discussed the influence of length on tractive performance of a track and there we found that a shorter track has to slip more to develop the same tractive effort as compared to a longer track. So, the longer track will slip less. So, it is better to have a longer track to develop more draft or more tractive force and we also discussed what are the procedure to be followed for selecting a tyre for a given tractor. Taking into consideration the maximum draft requiring tillage implement. That is all. You can have these papers and these books where it will be helpful for you by referring this. Thank you.