Traction Engineering
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Lecture 22
Selection of tyre

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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 lecture 22 where I will try to discuss how to select a tyre for a given size of tractor, what are the parameters we should consider.

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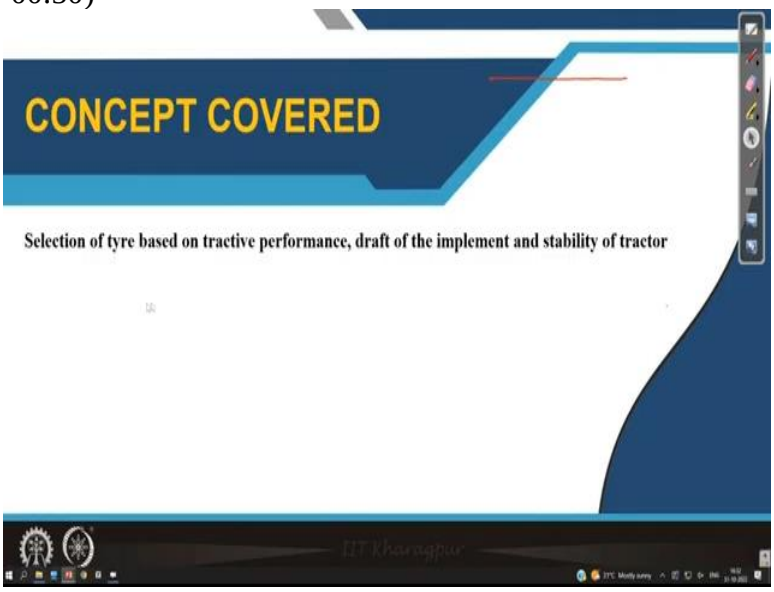

So, the concept will be selection of tyre based on tractive performance, based on draft of the implement and stability of the tractor. Stability means steering ability of the tractor.

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So, the tyre in case of off-road vehicle, you have to consider some of the factors, factors in the sense, what are the information on cost and load carrying ability of the various types of tyre which are available in the market. Information has to be gathered and it is available, it is available from the manufacturers. So, cost and load carrying ability number one, number two is

whether we have information on relative wear rates of different tyres, this is not very commonly available. Some studies have been conducted, but not much information is available in this aspect. Then the third thing is the cost to a farmer. If he selects a wrong tyre that means if he selects a smaller tyre, so, what is the cost he is going to pay for that? That means there will be more compaction there will be a reduction in crop yield. So, this information are available, if you increase soil compaction, how it is going to affect the performance or the yield of the crop. Then the fourth information is what is the tractive performance of tyre and how it is varying with changing diameter, changing width, changing stiffness. So, these are some of the information's which are required.

This information related to point four, they are not available readily. You have to develop that information and how to develop these information's? That we have to find out taking into consideration. What are the different models available and from there how do we vary so, that it is going to affect the performance? So, varying the tyre parameters like section width, like diameter and then stiffness we have to find out what is the corresponding change in performance change in coefficient of rolling resistance change in coefficient of traction.

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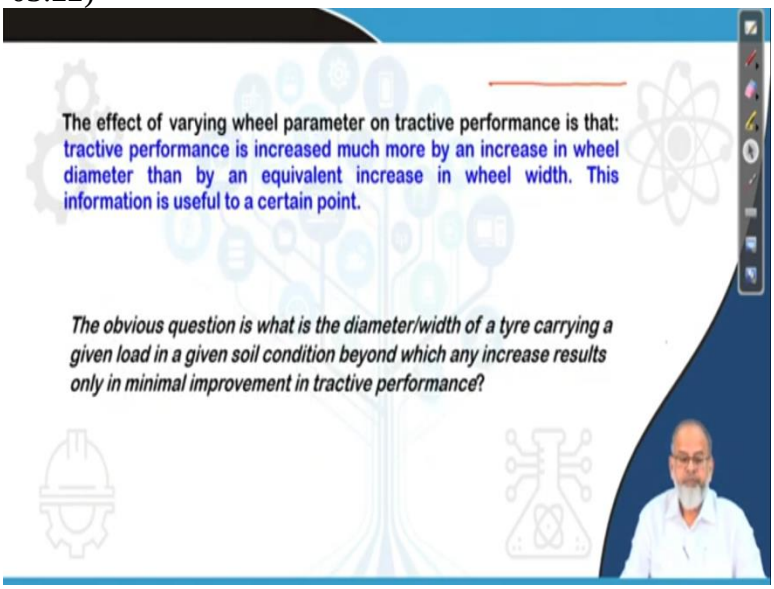

So, effect of varying wheel parameter and tractive performance is if we increase the tractor parameters there is increase in tractive performance but up to what diameter we can increase or up to what width we can increase that is not available. So, up to what width or what diameter for a given load and a given soil condition we can increase so that there is no minimal improvement

in tractive performance beyond that point, there should be sufficient amount of increase in tractive performance, so, you can go to that extent.

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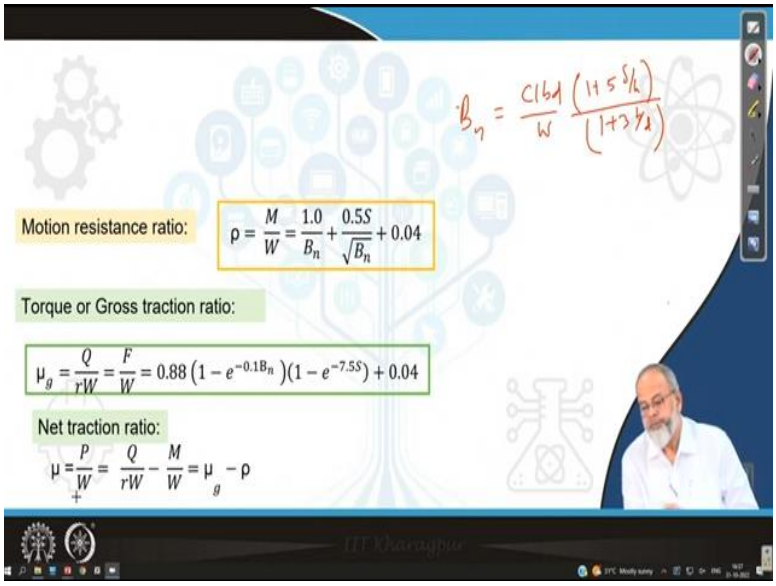

So, to do with that exercise, again we need Brixius equations as I said Brixius equation means, we need to know the motion resistance ratio we need to know how to calculate gross traction ratio we need to know how to calculate net traction ratio. At the Brixius equation is considering both δ/h ratio and b/d ratio. Hence, we prefer to utilize these equations based on Brixius findings.

So, again B_n is important mobility number and mobility number is nothing but

$$B_n = \frac{CIbd}{W} \times \frac{\left(1 + 5\frac{\delta}{h}\right)}{\left(1 + 3\frac{b}{d}\right)}$$

So, taking the help of mobility number we are done different slip values we can find out what is the coefficient of rolling resistance, what is the coefficient of gross traction what is and then from these two we can find out what is the coefficient of traction.

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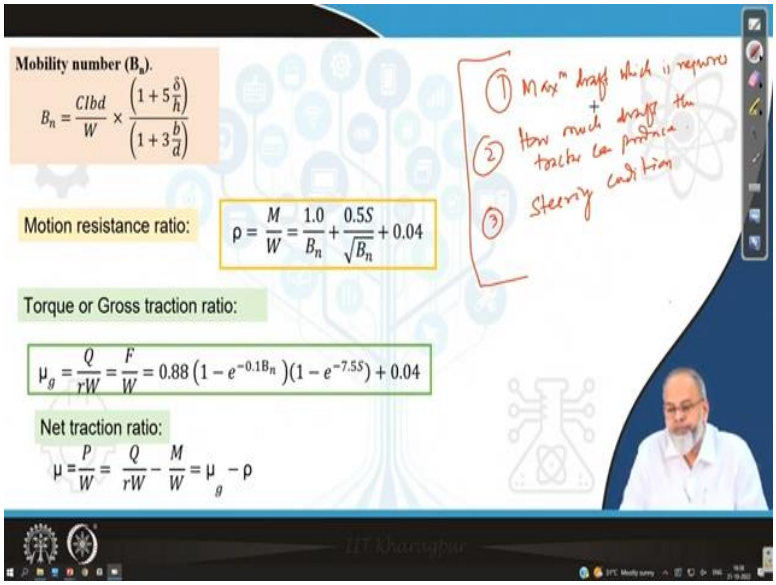

In a tractor when we try to recommend that this tractor should be fitted with this size of tyre that means, what are the considerations you have to take? The first thing is we have to find out what is the maximum draft which is required in the field. So, number one is what is the maximum draft which is required and number two is how much draft the tractor can produce and during production of this draft or the while finding out the pulling ability, what is the steering condition? Steering condition means whether sufficient weight is available in the front axle or not.

Because, if front axle sufficient weight is not available, then the tractor will try to float and steering becomes difficult. So, these are some of the considerations we have to see when I said maximum draft means it is obvious if you are operating in a moldboard plow which is the primary implement, there will experience more draft.

So, you have to take into consideration the moldboard plow and for calculating the draft we have to find out what are the equations available for estimating the draft value of different implements many equations are available but ASABE has given all those equations, it is better to consider ASABE equations rather than considering other empirical equations.

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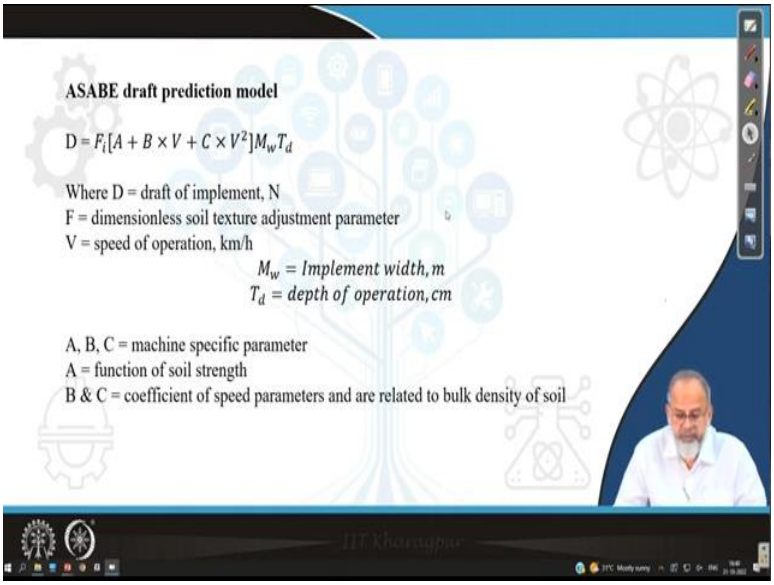

So, the first thing is we have to find out what is the draft and for finding out draft we use this ASABE equation is given as

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

So, now D is the draft of the implement that is in expressed in Newton, F is a dimensionless soil texture adjustment parameter and I value could be 1, 2, or 3 depending on the soil condition, then V is the speed of the operation which is expressed in kilometer per hour and M_w is the implement width in meter, T_d is the depth of operation in centimeter, A, B and C the machine specific parameter, A is the function of soil strength; B and C these are coefficients of speed parameters and they are related to ball density of soil, in fact A, B and C they are related to strength of soil.

No doubt there are some limitations of this, but ASABE itself says there is ±50 percent variation, but still then this is the most reliable equation available, so, that is why we have taken this equation.

Now, for a mouldboard plow if you want to find out then you have to decide the value of A, B, C which are given in that standard and then the taking into the forward speed V and the depth at which you want to operate we can calculate what is the draft requirement depending on the implement width and depending on the soil condition.

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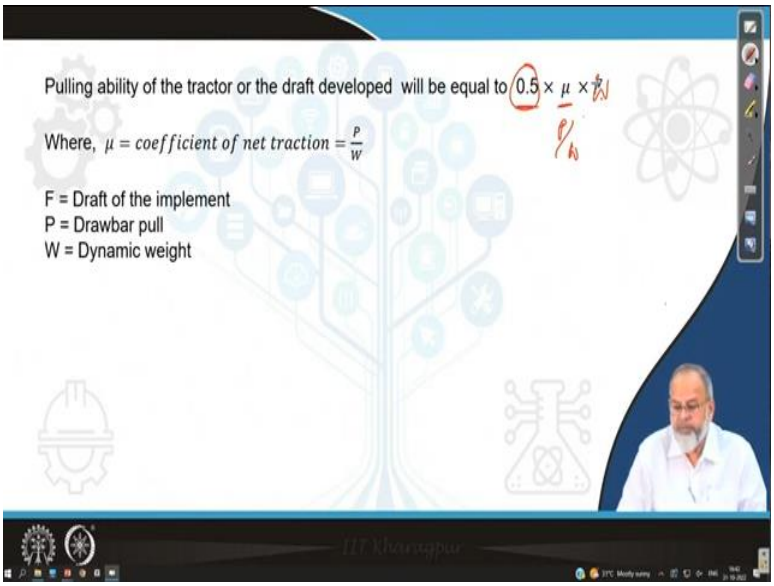

The second question is what is the pulling ability of the tractor if you know the soil condition first you have to define the soil condition then in that soil condition, what is our HP of tractor that is important because HP of tractor will decide how much will be the weight, weight of the tractor and then you have to take the static weight distribution. So that 65 percent and the rear axle or maximum we can go up to 70 percent on the rear axle.

Then we try to find out the coefficient of rolling resistance then you try to find out what is the gross tractive effort then you try to find out what is the coefficient of traction knowing the weight you can find out what is the pulling ability or pull developed this pull should match the pull with the pull which is required by the moldboard plow that gives you the maximum draft.

So, while calculating the pulling ability again we have considered one parameter that is a power reserve we can take we have taken us 50 percent, 0.5 why, because ASABE equation itself says there is the variation of drop from ±50 percent 40 percent like that. So, that is why you have to keep a very high value of reserve. So, 0.5×μ, μ is nothing but P/W and then this is W so, that will give you the pulling ability of a tractor.

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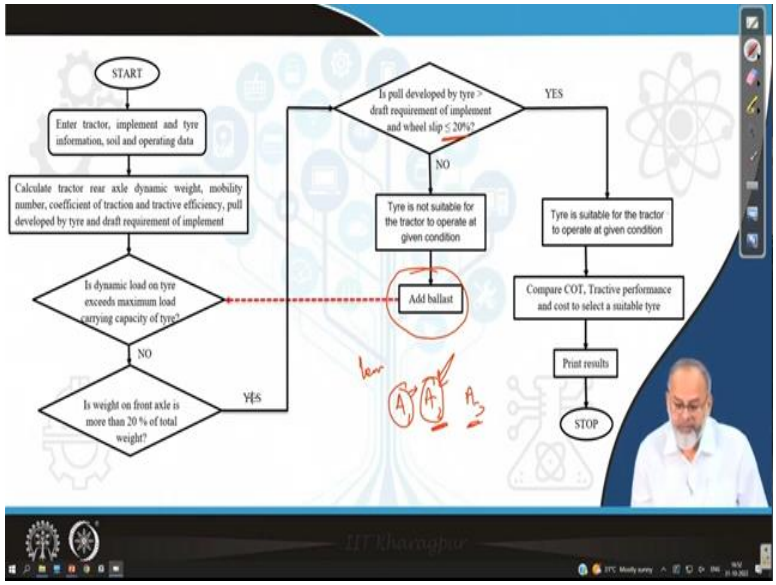

So, this exercise is to be carried out so, I have done a flowchart for this how to carry out this exercise. So, the first thing is, you have to gather information on tractor on implement and then what are the soil conditions? And what are the operating parameters? Like what is the speed of operation? What is the depth of operation? So, all those information's you have to gather.

The next thing is we have to calculate the tractor rear axle dynamic weight because while calculating COT or coefficient of rolling resistance we need to know what is the actual weight which is coming in the rear wheel, so, that is we are interested in finding out the dynamic weight, dynamic weight coming in the axle.

Then, we will try to find out mobility number and coefficient of traction, tractive efficiency and the pull developed by the tyre and the draft requirement of implement that means, here we want to utilize the Brixius equations for calculating the tractive performance parameters such as mobility number is the main then we calculate the coefficient of traction and tractive efficiency. See, tractive efficiency is nothing but

$$Tractive\ efficiency = \frac{\mu}{\mu_g} \times (1 - s) = \frac{COT}{GTR} \times (1 - s)$$

So, once you calculate μ, once you calculate μ_g which is nothing but the torque ratio which is given by Brixius then at what slip we are operating, so, from there you can calculate what is the tractive efficiency. So, tractive efficiency then pull developed from there knowing the dynamic weight you can calculate what is the pull developed. So, while calculating the pull developed you have to take both the tyres into consideration.

So, total pull developed then keeping a factor of reserve then that becomes here the power which is available and that power sorry, that pull should be equal to the draft required by the implement and this draft requirement by the implement this will be computed by using ASABE equation.

So, we have two sets of equation one is Brixius for tractive performance and we have ASABE draft equation for calculating draft. So, these are the two equations to be followed. Next is once you know the while calculating the pull coefficient of traction then we have to find out what is the dynamic weight coming. Now, when the dynamic weight comes into picture, then we have to find out whether the dynamic weight the tractor can carry or not.

So, is the dynamic load on tyre exceeds maximum load carrying ability that is one point. If it is no then is the weight on the front axle is more than 20 % of total weight. Why this is important? Because this 20 % weight on the front axle is required otherwise the tractor will be difficult to steer, so, this is another requirement, if the first requirement the loading abilities okay that the tyre can able to carry then the second thing is after weight transfer, what is the weight which is left on the front axle whether that is a more than 20 percent or not.

So, once this is satisfied, if it is yes, then we go to the pull which is developed by the tyre utilizing Brixius equation keeping a power reserve. So, once the pull is calculated, then that has

to be a checked with the draft requirement, draft requirement by the implement and this is calculated taking into ASABE equation.

Now, if it is satisfied, then the pull which is developed by the tractor should be within the wheel slip of 20 percent because as you know, if you exceed wheel slip of 20 percent your tractive efficiency is affected considerably. So, the pull which is required and which has to be match with the draft requirement of the implement that pull should come within a wheel slip of 20 percent.

So, that is why we have kept a bar here that means the wheel slip should be less than equal to 20 percent if this condition is satisfied yes then the tyre is suitable for tractor to operate at a given condition, given condition means given soil condition given operating condition if it is no then the tyre is not suitable for the tractor to operate at given condition.

So, what are the possibilities? How do we make this tyre suitable? The only possibility is we increase the weight we can add certain weight which is called ballasting. So, when we add certain weight, so, then again, we check after adding the weight because we are adding weight to reduce slip. So, when we add weight so, then again you have to carry out the exercise like whether by after addition of weight whether the tyre is in a position to carry the load or not or the total weight including ballasting should be less than the load carrying ability of the tyre.

Again, we check after addition of weight when you try to pull it what is the weight transfer from the front as well as the from the implement side and what is the dynamic weight which is coming on the rear axle and the dynamic weight on the front axle. If the dynamic weight on the front axle is less than the 20 percent of the total weight, then we do not accept it.

So, this is the condition which will check the dynamic weight should be more than the 20 percent of the total weight dynamic weight of the front axle should be more than 20 percent of the total weight of the tractor. If this condition is satisfied, then we go for checking the pull which is developed the pull which is developed should be developed by the tractors should be greater than the draft requirement of the implement. So, here again that 50 percent reserve will be taken and if this condition is satisfied and wheel slip is less than 20 percent then we will say that the tyre is suitable if not then this loop will continue.

So, once the tyre is suitable the next thing is you have to find out what is the COT? What is tractive performance in terms of tractive efficiency? And what is this cost? Why because? Suppose two or three tyres they simultaneously satisfy this condition it may be possible that there will be two or three tyres which will satisfy this condition.

Then comes your economics part, economics part means what is the cost we have to incur when we try to purchase those tyres and what is the benefit we are getting if say tyre A1, A2, A3 these are the three tyres we satisfy and satisfy this condition and A1 is the tyre which is giving you which is available at lesser cost as compared to A2 or A3 then it is better to go for A1 tyre or if the slide change in price you are getting little more benefit in traction for example in A2 then you prefer A2.

So, these are all economical decisions, the technical decisions, these are all dependent on basically three things one is what is the draft requirement? And what is the pull which is developed? And whether the pull is developed within 20 percent of wheel slip or not? And then what is the weight coming in the front axle? So, front utilization front weight utilization factor.

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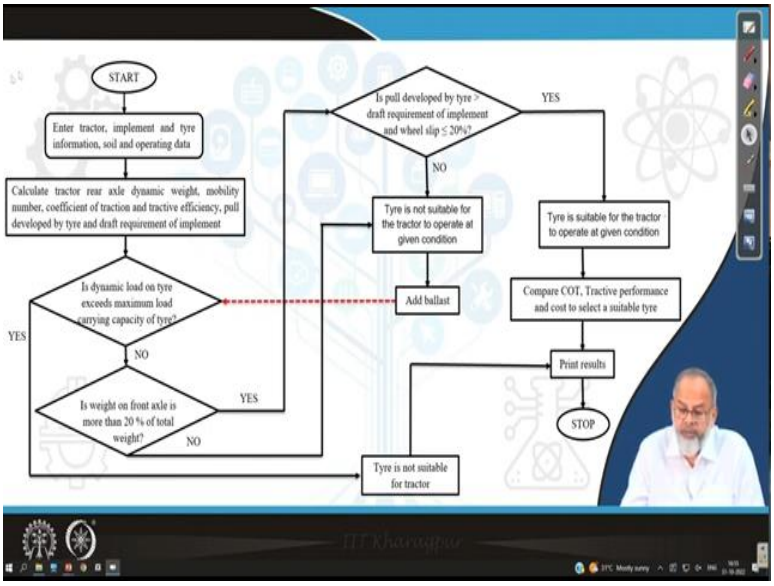

So, these are some of the things which has to be considered while selecting a tyre. So, this is the flowchart which I have given. So, the complete flowchart, first tyre specification, implement specification, soil conditions, operating conditions, then you compute different parameters traction parameters and draft value then comes your comparison whether the tyre is in a position

to carry the load dynamic load or not? If not weight on the front axle is less than 20 percent or not.

Then if those conditions are satisfied that means the tyre cannot take this load and there is weight on the front axle which is 20 percent lesser then it will say the tyre is not suitable for tractor, if these conditions like a wheel can carry the dynamic load it is less than the load carrying ability of the tyre and front axle weight is 20 percent then it goes to compare whether the pull is equal to the draft which is required and if that is so, whether the pull is developed within 20 percent or not, 20 percent of wheel slip.

If this condition is satisfied immediately, you can say the tyre is suitable for the tractor. So, these are some of the procedures which we have to follow. So, again what you can say is the important thing is we should know how to calculate these performance parameters. And obviously, there are many equations available as I said, it is the Brixius equation which has to be considered because of its inclusion of δ/h ratio b/d ratio and the wide range of applicability. So, that will help you in calculating the tractive performance parameters and that will also help in calculating, what is the pull which is required to be developed by the tractor?

Then the second important component is your draft requirements. So, though many equations are not available only a few are available out of these few we have to go for ASABE draft equations where we can give variety of implement can be utilized and their draft values can be computed.

So, thing is we have to go for moldboard plow why because? This is the primary tillage implement which is giving you maximum draft that is why I indicated that we should utilize moldboard plow. So, these are the two important equations you have to consider then the third important parameter is the wheel slip that should be within 20 percent and the fourth important is your steering ability that relates to the front wheel weight coming in the front axle.

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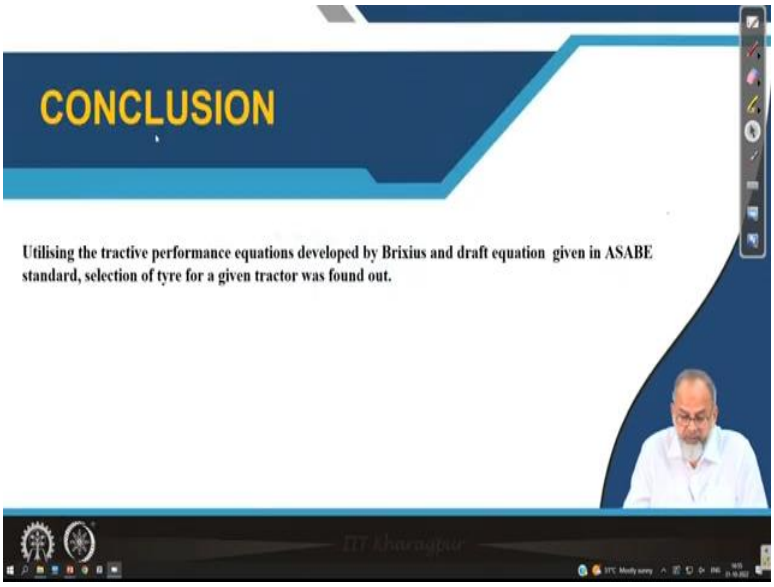

So, in brief we can say utilizing the tractive performance equation developed by Brixius and draft equation developed by ASABE and is available in ASABE standard, selection of tyre can be carried out taking into consideration the front wheel weight utilization factor that is 20 percent of the total weight of the tractors should be always available at the front axle for easy steering.

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So, you can refer summer to the ASAE standards then you can use the theory of ground vehicles book that will help you in further improving your knowledge related to computation of different parameters and thereby you can select the tyre in a better way. Thank you.