Traction Engineering
Professor Hifjur Raheman
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur
Lecture 26
Measurement of Cone Index

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 26, where I am going to discuss about how to measure the cone index.

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The concept will be, the strength of soil, is basically, cone index represents the strength of soil and we are interested in measuring strength of soil because, when there is a traction related studies, it is the soil and wheel interaction which will result in development of a tractive force. So, what is the strength of soil that will indicate or that will going to develop the tractive force. So, that is why this parameter is important.

And there has been a standard defined by American Society of Agricultural and Biological engineers, how to measure strength of soil. So, in this class, I will try to follow that standard and I will try to explain how to utilize those procedures in measuring the code index. So, basically, we will be taking a static cone penetrometer and that has to be pushed into the soil at a steady rate. So, how I am going to utilize this cone penetrometer in the soil bin that I am going to demonstrate

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Hi everyone, this is professor H Rahman from Agricultural and Food Engineering Department, IIT Kharagpur, I welcome you all to this NPTEL course on traction engineering. Today I will try to discuss about how to evaluate the tractive performance of a single wheel, the set of which you are looking, which you are seeing now, this is the unique set of which we developed at IIT Kharagpur where we try to find out the tractive performance of a single wheel.

So, we have to have a soil bin, so these are 15 meter soil bin, where we can vary the soil conditions and we can also vary the operating conditions so that the tractive performance can be evaluated at different conditions. You can change the tyre, we can change the load, we can change the pressure, we can change the soil condition, and the parameters which are going to measure is the cone index of the soil which will indirectly give you the strength of the soil.

Then, we will try to find out the moisture content and then how much pull you have applied then corresponding slip has to be measured then tractive efficiency. So, these are the parameters which are required to evaluate the tractive performance of a tyre. So, to start with, I will first explain how to measure the strength of soil using a static cone penetrometer.

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There is a cone penetrometer meter which has been, the cone has been removed from this shaft to which it will be attached. This cone along with this shaft has to push, has to be pushed into the soil of the soil bin, and how much force we are applying that has to be recorded. And the base area of this cone is 3.23 square centimeter and the angle of the cone is 30°.

So, once you know the how much force you have applied, divided by the base area that will give you the cone index and this has to be measured at different depths depending our requirement. So, I will now explain or I will now demonstrate how this cone penetrometer is pushed into the soil.

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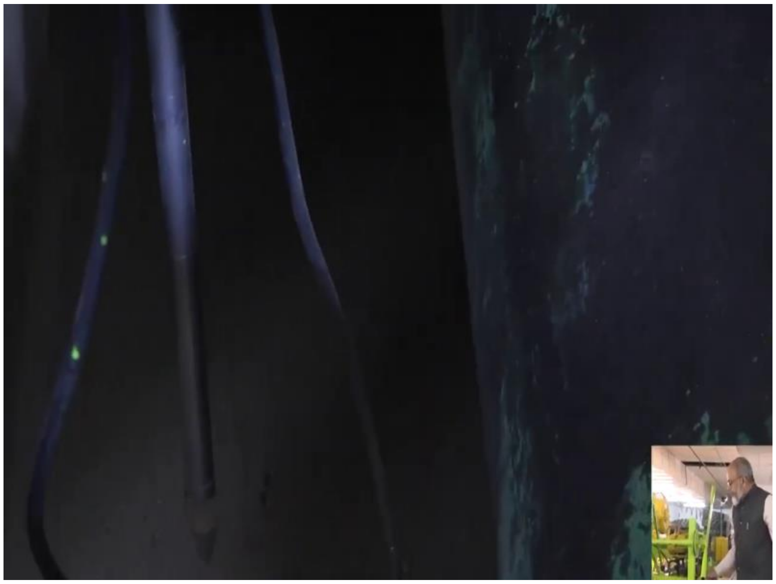

Now I will demonstrate how to measure cone index of a particular soil. This is the soil bin where I am going to find out what is the strength of the soil in the soil bin. So, the instrument which are required is the cone penetrometer. The cone penetrometer is this one, the base of that, there will be a cone shaped probe. And on the top, there will be a load cell which is going to sense the force which is applied. Now force if you know divided by the base area that will give you cone index. Now, you have to measure that cone index at different depths. So, you have to measure the depth as well as the force. So, for measuring depth, we need to know how much depth it has entered.

So, we have done it with the help of a potentiometer here. So, when you change, when you move it up and down the resistance of the potentiometer changes, so when the potentiometer has already been calibrated. So, once you know the change in resistance, we can find out how much depth it has entered. Similarly the load cell has also been calibrated.

So, how much output, electrical output is coming that has to be expressed in terms of how much load you have applied or the how much force you have applied. Now, I will show you how to measure the cone index. So, initially the cone has to be pushed into the soil, so that the base of the cone is just passed with the soil surface.

Now, you can see the base is already flush with the soil. So, that is the 0 line. Now, we have pushed that probe into the soil. So, it has gone to a certain depth and this is possible by utilizing a hydraulic power. So, you are utilizing hydraulic power to force that cone shaped probe into the soil. Now, it is lifting that cone penetrometer from the soil beam, so again it is the help of a hydraulic power.

So, it is basically a two-double acting hydraulic cylinder; the one-way is used for pressing that probe into the soil the other way is using to lift that cone penetrometer from the soil.

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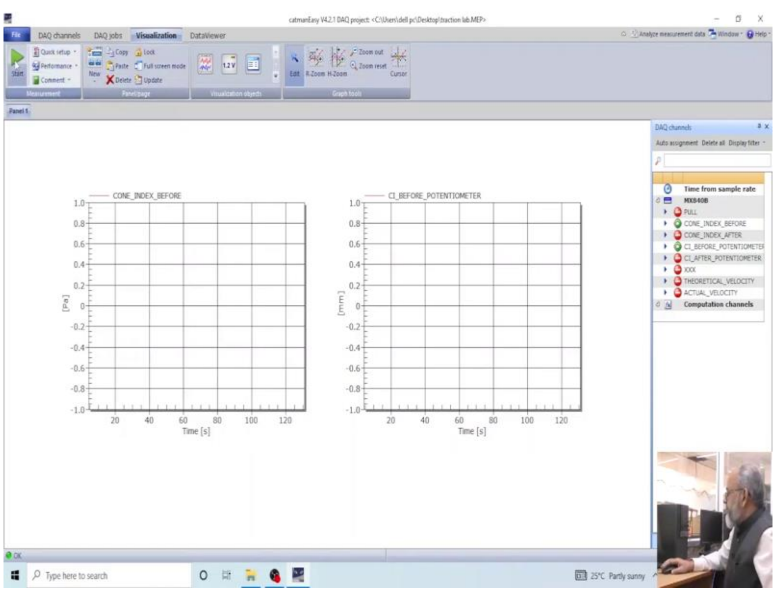

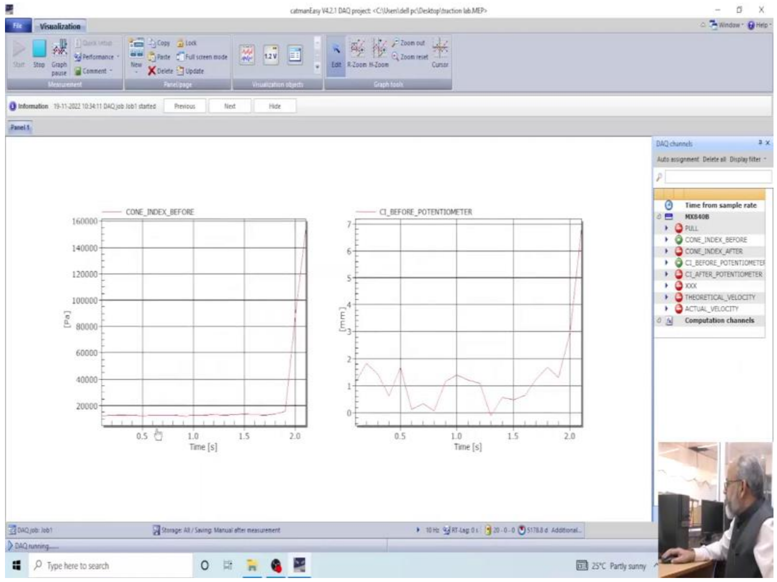
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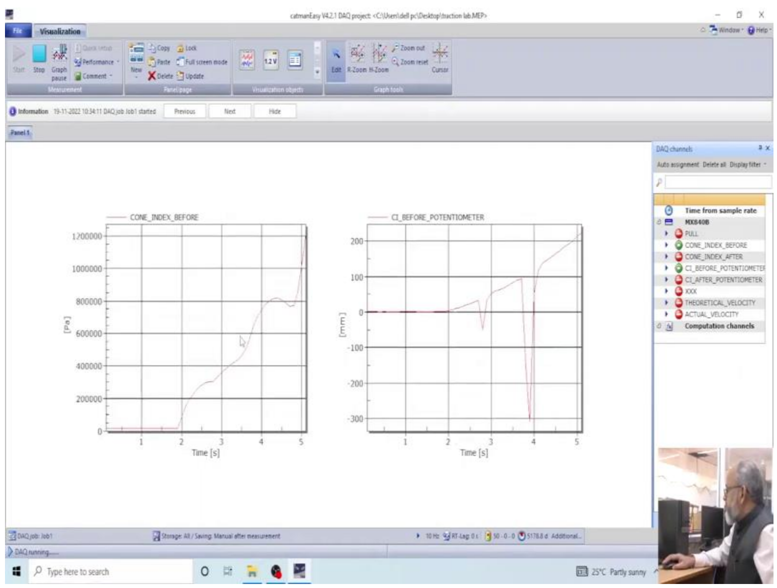
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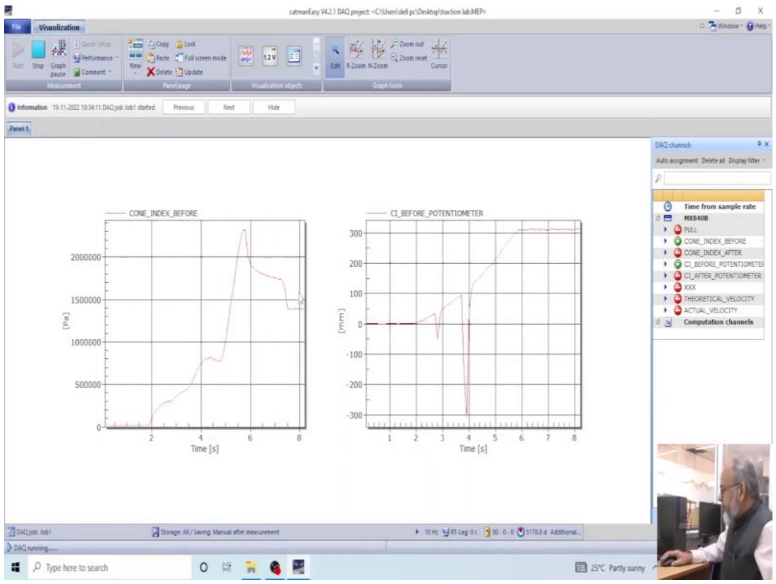

Now, I will show you how the cone penetrometer readings are recorded. So, initially it will show the 0 value. So, you can see there is no, now, it has started. The cone index has started, so, along with the depth. So, this slide shows the cone index in Pascal and that is versus time and the second graph shows the depth, how much depth you have entered that probe into the soil and that is versus time.

So, you have data related to cone index, we have data related to depth. So, now, we can find out, we can have a plot of cone index versus depth. From here we will find out what is the average cone index in the entire depth at which you have push that cone penetrometer. When you have stopped pushing this, so you can see it has reached a maximum after that it is a showing almost constant, that is, that means, we are not pushing any further.

So, that is the maximum, that we have gone up to 300 millimeter. And now, we will see how it or what will be the cone index corresponding to this 0 to 300 millimeter depth. Now, the data which has occurred that has been plotted. You can see on the x axis, this is depth in millimeter and y axis you have cone index in kPa.

So, you can see, we have started from 0 and it has gone up to 300 millimeter. So, it is slowly increasing and the area which is bounded if I draw a vertical line here and this area has to be calculated either graphically or using software which is available and then by dividing that depth we can find out what is the average cone index of that soil that particular area.

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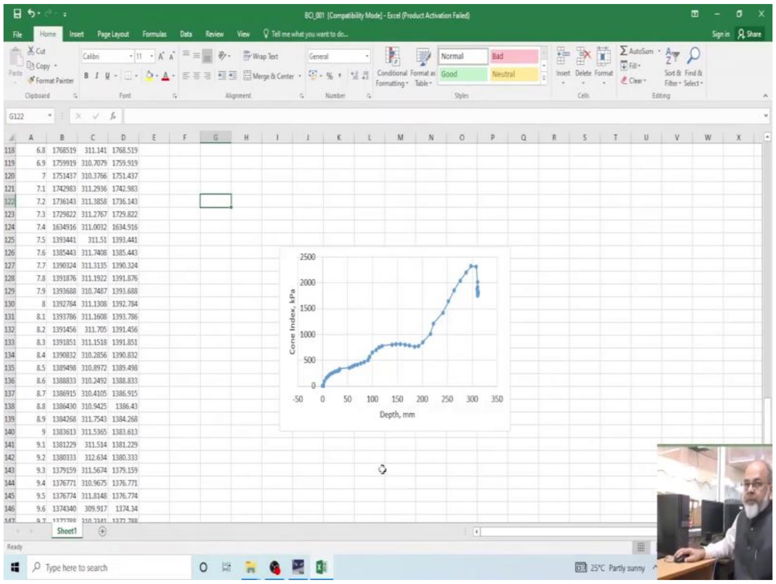

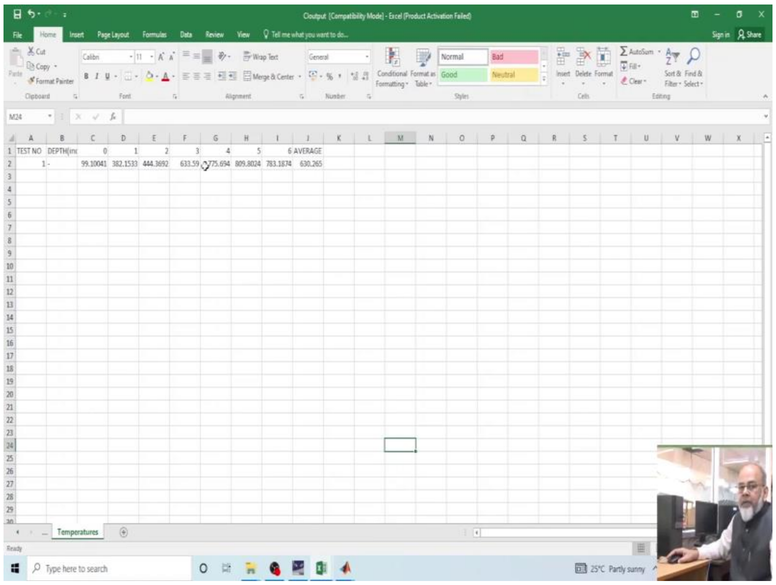

Now, I have calculated the average cone index at different depths. You can see at 0, it is 99.1 kPa, at 1 it is 382 kPa or 2, it is 444 kPa and 3, it is 633 kPa and at 4, it is 775 kPa and at 5 means 5 inches, it is 809 kPa, then at 6 inches, it is 783 kPa. So, then we have average from 0 to 6 that comes around 630.265 kPa.

So, that is the average depth at that particular spot where we have carried out the pushing of cone penetrometer. The similar exercise you can carry out at different places of the soil bin, at least 4 to 5 places so that we can have the average cone index. So, you will got values like 630 then there will be another 5 values if you are taking 5 observations. Then you take the average that will give you the average cone index of the soil which is present in the soil bin.

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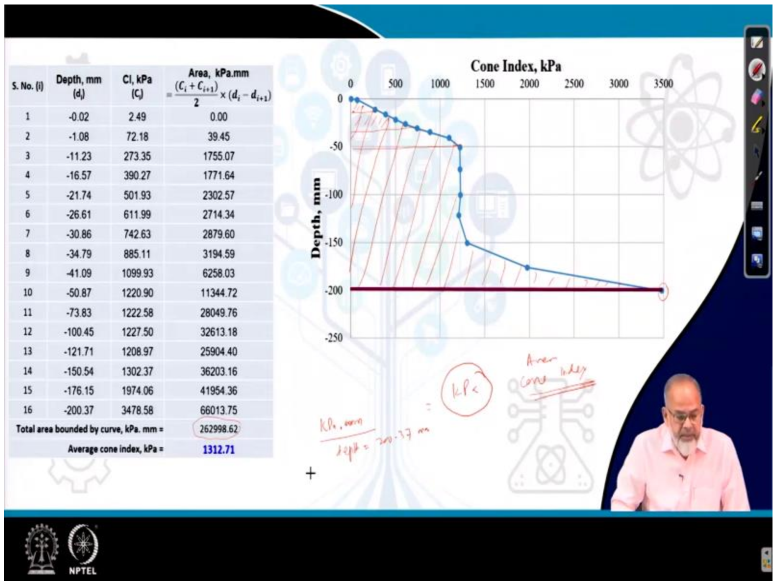

So, cone index as I said, is the force required to cause a cone shaped probe into the soil. We want to push the cone shaped probe into the soil. So, what we are going to measure is the force which is required to push it into the soil, the cone which we will be taking is around 30° cone angle which is basically of 3.23 square centimeter.

Now, if you know the force, then force divided by that base area will give you how much is the cone index. So, that has to be measured at different depths. So, to measure the force, we need to have a transducer or a loadcell which is, which has to be attached to the shaft on which the cone is attached. So, the output of that load cell will be recorded in the computer, it using a data acquisition system.

Similarly, we are also interested in measuring the depth, what is the corresponding depth at which you are measuring force. So, to measure for depth, we require a, we utilize a potentiometer. So, potentiometer is nothing but when you change the resistance of the potentiometer there will be a change in output, electrical output and that is calibrated against the depth. So, basically the output from the potentiometer and the transducer are indirectly giving you the depth and the force.

So, the data which you obtain is like this. So, this is the, in the second column you can see, these are the data related to depth and in the third column, I have already calculated the cone index that means the force whatever we got that is divided by the cone base area, so directly you are getting cone index in kilo Pascal.

So, at different depths, what are the corresponding cone index that data we have. Then from these data, how to calculate the cone index that is important. So, first thing is, we try to plot it. So, depth is on the y axis and cone index is on the x axis. So, now, at different depths, these are the points which you got. So, this is the shape of the curve.

Now, the area bounded by this curve has to be found out. So, for finding out the area bounded by the curve, we first draw a horizontal line at the last point. This is the last point. This is the point, there I draw a horizontal line parallel to the x axis and this is the area which has to be calculated. So, you can follow the trapezoidal rule and then find out at different depths what is the area and then take the summation of those area.

So, that will give you the total area. So, what I have done here, I have calculated the area by taking like this at different depths okay. So, this is a triangle, this is a trapezoidal, trapezoid, this is a trapezoid so like that will divide this area into different types of trapezoid and then following this equation $(C_i + C_{i+1}) \times (D_i + D_{i+1})$ that means, this will give you the height this will give you the base and the top of the trapezoid.

So, that way you will find out what is the total area contained in this small section, in this trapezoidal section like that. So, that way we have calculated for all the depths and then finally, what we get is summation, summation of this area which comes around 26,000 to 62,998.62 and the unit is in kPa and millimeter because I have calculated cone index in kPa and depth I have measured in millimeter.

So, area is represented as kPa, kPa × mm. Now, what is the cone index value, so I just divided by depth, total depth. So, total depth becomes say 200.37. So, this divided by depth which is 200.37 this is again millimeter. So, what I am getting, what I will get is kPa, so this is the value of cone index.

This is average cone index for a depth of 200 millimeter, so similar exercise has to be carried at 3 or 4 places in a soil bin. If you are carrying out the test or in the field you can have more number of points. So, then we try to find out at each point what is the cone index, average cone index, then you find out the average cone index and then find out the standard deviation.

So, you have to mention that this is the cone index with a plus or minus value of a standard deviation. So, which we will represent the cone index of that particular plot or in the soil bin what is the average cone index. So, this is the procedure then how does it reflect the strength of soil. In fact ASABE has divided into 3 categories: soft soil, medium soil and firm soil.

Soft soil is 450 kilo Pascal and medium soil is 900 kPa and 1800 kPa is your firm soil or the hard soil. So, now, in our case we are getting a value of 1,312.71 kPa that means, this is more than the medium soil but lesser than the hard soil. So, we can say it is nearly hard soil so that this is the way which we have to follow to measure the cone index and how to utilize those data to find out the average cone index. Thank you.