Engineering Hydrology

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Lecture 35

Measurement of Infiltration

Hello, all. Welcome back to the lecture on infiltration. In the previous lecture we were discussing about infiltration process. We have seen factors influencing infiltration, what is meant by infiltration and also different ways of expressing infiltration, that is, potential infiltration and actual infiltration. If sufficient amount of moisture is present in the soil, then the infiltration taking place is termed as potential infiltration, and the infiltration which is actually taking place is termed as the actual infiltration.

At that time, the soil moisture which is present will be less than that of the maximum amount of soil moisture that can be stored within the pores present in the soil. So, today, let us move on to the measurement of infiltration.

So, how can we measure infiltration, and also how can we estimate? So, measurements are coming under experimental techniques, and estimation comes under mathematical techniques for estimating infiltration. So, today we will see what are the different measurement methodologies for getting infiltration.

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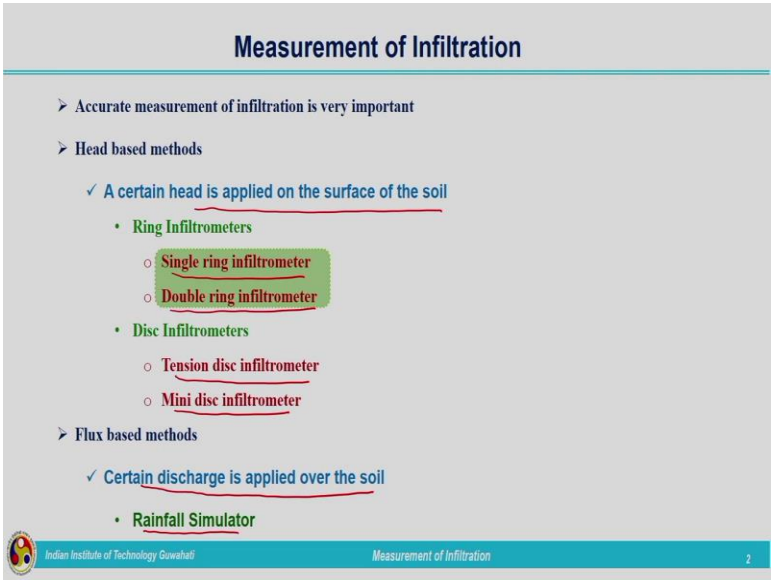

Accurate measurement of infiltration is very important in the case of watershed modelling and how much water is infiltrating into the ground and separating the rainwater into runoff and the one component which is moving into the ground. So, for the determination of all these things we need to have the accurate measurement or the accurate estimation of infiltration.

Based on the different approaches utilized for measuring infiltration, it has been divided into two; one is termed as head-based method, and the other one is flux-based method. As the name indicates, in the head-based method, a certain head is the driving cause, that is the force which is causing the infiltration is the head which is prevailing on the ground.

And in the case of flux-based approach, we will be providing certain flux or intensity of water. It may be in the form of rainfall or it may be by means of sprinkling water. So, different methods utilized by making use of these techniques, we will see.

Under head-based approach, a certain head is applied on the surface of the ground. If it is a field experiment to measure infiltration, on the ground surface there will be a particular depth of water provided. That may be due to rainfall or maybe due to agricultural

activities or artificially created for the measurement of infiltration. So, under this, the commonly used techniques are ring infiltrometers, and disc infiltrometers.

Conventional approaches in head-based methods are ring infiltrometers. Ring infiltrometers commonly used are single ring infiltrometer and double ring infiltrometer. And coming to disk infiltrometers, two commonly used disk infiltrometers are tension disc infiltrometer and mini disk infiltrometer. So, in this case, that is, head-based approach, we are providing a certain head of water which allows the water to infiltrate into the soil.

So, different approaches, ring infiltrometers and disc infiltrometers. Under ring infiltrometers, we are having two kinds, one is the single ring infiltrometer and second one is the double ring infiltrometer. And in the case of disk infiltrometer, commonly used are tension disk and the mini disk.

The difference between ring infiltrometers and the disk infiltrometers are, in the case of ring infiltrometer a ponded depth of water will be provided, that is, a positive head of water will be causing the flow or causing the infiltration. So free flow is allowed there. But in the case of disk infiltrometer, the flow is taking place under a negative pressure or negative head. So, we will be providing a negative head within the disc infiltrometer that will be making some constraints to the free flow of water.

Now, coming to the flux-based approach. In this, what we are doing, we are providing certain discharge over the soil. That discharge may be the rainfall, that is, intensity of rainfall or sometimes artificially we will be creating the fall or discharge by means of certain nozzles provided on the pipes. And one flux-based method is rainfall simulator. This is also commonly used, mainly in the field measurements. So, rainfall simulators are working on the principle of flux-based approach. In this, artificially we are creating the rainfall. So, based on the water which is infiltrating into the ground, that will be measured, or we will be collecting at the outlet how much is the water flowing as runoff. So, that way we can calculate how much will be the infiltration taking place in the case of rainfall simulator.

In this lecture, we will be concentrating mainly on two infiltrometers. Those are ring infiltrometers, that is, single ring infiltrometer, and double ring infiltrometers. These are the conventional infiltrometers, simple techniques which are used for measuring infiltration.

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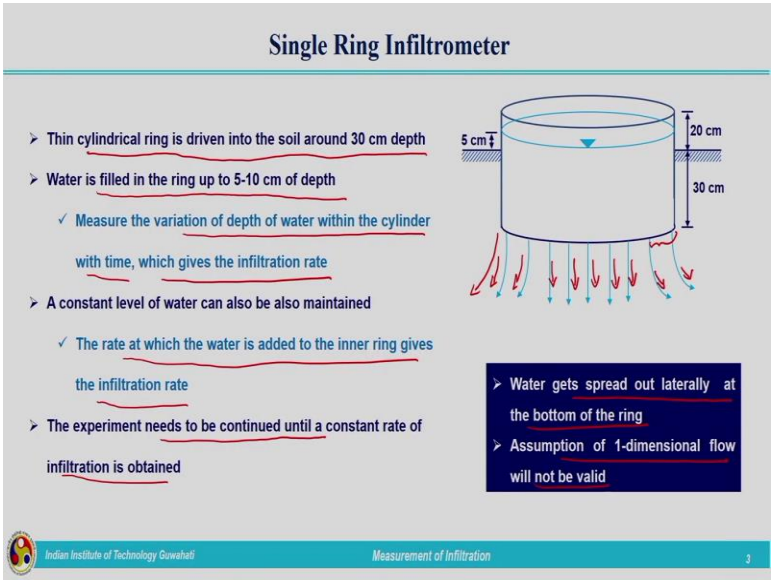

First one is the single ring infiltrometer. In this, what we are doing, a thin cylindrical ring is driven into the soil around 30 cm depth. As the name indicates, this single ring is a cylinder having a small thickness. That cylinder will be inserted into the ground.

Let this be the ground surface. We are going to insert the cylindrical ring into the ground up to approximately 30 cm depth. Sometimes depending on the soil strata, it will be very difficult to insert this much depth, but as much as possible, we will be inserting into the ground.

Different types of rings which are having standard dimensions are available. So, here, the one which is shown is having a depth of 50 cm. Out of that, 30 cm will be inserted into the ground and 20 cm will be above the ground surface. And after that water will be filled in the ring up to 5 to 10 cm of depth.

So, after certain time, the water will be infiltrating. Once the water is filled inside the ring infiltrometer, water starts infiltrating into the ground. So, if we are taking this much of water infiltrated into the soil within this much of time, that will be giving us the infiltration rate.

Sometimes it can be done in such a way that instead of measuring the lowering of water level, or how much reduction is taking place in the water level, we can maintain a constant level. And as the level is dropping down, we can add water into the ring in order to maintain that constant level. So, the volume of water which is added to the ring and the corresponding time will be noted down to get the infiltration rate.

So, in both the ways it can be done, either by maintaining a constant head or by measuring the falling head. In the case of constant level, the rate at which the water is added to the inner ring is measured, and that will give us the infiltration rate. And this needs to be continued, the experiment needs to be continued until a constant infiltration rate is obtained.

Initially, the infiltration rate will be high because the soil will be considerably in a dry condition. In such cases, water will be infiltrating at a higher rate initially so that, the quantity of water which is required will be very high. So, depending on the type of the soil or depending on the moisture which is present in the soil we may have to continue the experiment for long time until it reaches a constant rate of infiltration.

So, here you can see, in the middle portion, central portion, we are getting correct downward flow. It can be considered that the flow is taking place in the z-direction or flow is one-dimensional. When it comes to the sides of the infiltrometer, the lateral flow is taking place. You can see the flow slowly spreads in the lateral direction.

So, in this case the main disadvantage is that we are assuming that the flow is one-dimensional. And at the same time, the water which is infiltrating is not following the one-dimensional path. At the sides of the infiltrometer, it is spreading in the lateral

direction. So, water gets spread out laterally at the bottom of the ring. So, the assumption of one-dimensional flow will not be valid.

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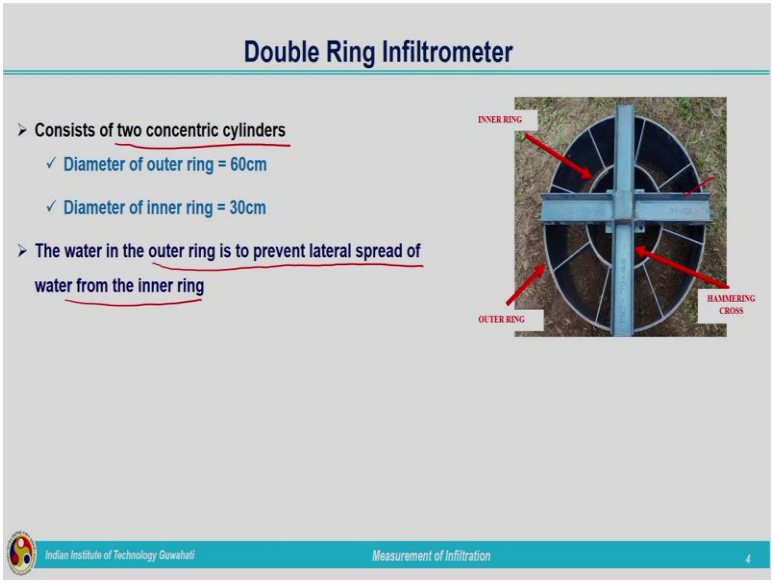

So, in order to overcome this disadvantage, double ring infiltrometers have been developed. It consists of two concentric cylinders. This is the photograph of the double ring infiltrometer.

So, it is having an outer ring which is having a diameter of 60 cm, and inner ring is having a diameter of 30 cm. For this also, standard dimensions are available. So, here the one which is shown is having 60 cm outer diameter and 30 cm inner diameter. And a hammering cross is provided to prevent the damage which will happen while hammering on the rings. So, we will be inserting the ring by hammering on this hammering cross. The water in the outer ring is to prevent the lateral spread of water from the inner ring. Here we will be filling water in both the rings. So, the lateral spread will be taking place only from the outer ring. Inner ring, we can maintain the one-dimensional assumption.

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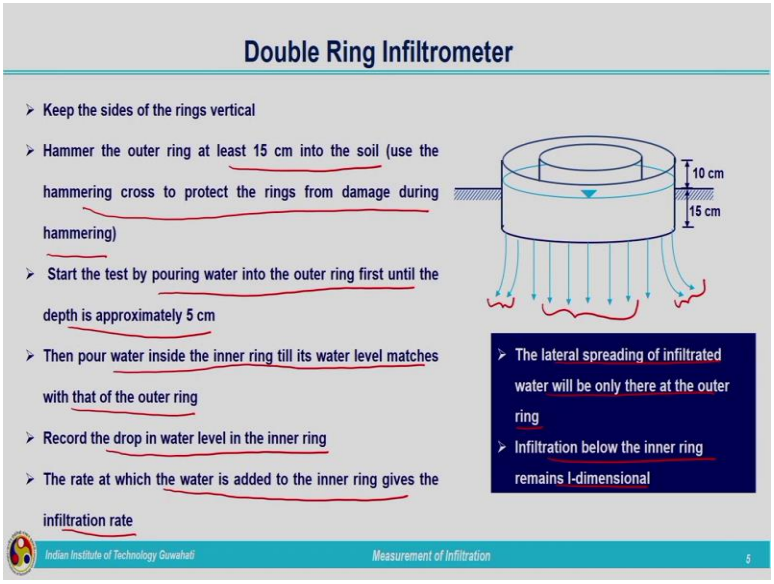

How, the double ring infiltrometer works? The ground may be having some undulations and all. So, we should be careful while placing the infiltrometers. The sides of the infiltrometer should be vertical. After that, we will be hammering that infiltrometer into the ground. So, outer ring is hammered inside the ground, at least 15 cm into the soil.

So, hammering cross is used to protect the rings from damage during hammering. So, it is not that easy to hammer it. So, if the ground surface is very compacted surface, then it will be more difficult to hammer the ring into the ground. So, this way, we will be inserting the outer ring first. Almost 15 cm, it will be going inside the ground, and 10 cm above the ground surface. And in the similar way, we will be inserting the inner ring also.

After that, we will start the test by pouring water into the outer ring first, until the depth is approximately 5 cm. Initial filling is done with the outer ring. And once the outer ring is filled up to 5 cm, 5 to 8 cm, we will pour water inside the inner ring till the water level matches with that of the outer ring.

The level in both the ring should be maintained same level because the flow which is taking place into the ground or the infiltration taking place is due to the positive head or the ponding depth or the water depth which is allowed to be there on the ground surface.

The influence of this is there while the infiltration is taking place beneath the ground surface. So, this water depth, which is provided at the ground surface or within the rings is having a role while infiltration takes place. So, we will be filling both the rings at the same level.

Now, the measurement will be done as we have done in the case of single ring infiltrometer. The water will be infiltrating into the ground. Here you can see the lateral spread is from the outer ring only. Inner ring, you can see, almost entire water is flowing in the one-dimensional way. So, we can consider the flow which is taking place at the central part, infiltration which is taking place from the central ring or the inner ring is following the one-dimensional assumption. But when it comes to the outer ring, lateral spread is there.

Now what we will be doing? We will be recording the drop in the water level in the inner ring. So, while doing the measurement, we are considering only the inner ring. How much water is added or how much lowering of the level taken place within the inner ring that we will be doing with respect to inner ring only. And the rate at which the water is added to the inner ring gives the infiltration rate.

So, in this case, we are using the drop in the water level. Otherwise, we can maintain a constant water level and the rate at which water is added between certain interval of time can be utilized for calculating the infiltration rate. So, here, the advantage is that the lateral spreading of infiltrated water will be only there at the outer ring. Infiltration below the inner ring remains one-dimensional.

If only a single ring is present, lateral spread will be there which will be causing extra flow of water rather than which is expected. But in the case of double ring infiltrometer, this lateral flow is from the outer ring. Inner ring is providing only the infiltration in the vertical direction. We can consider it as one-dimensional.

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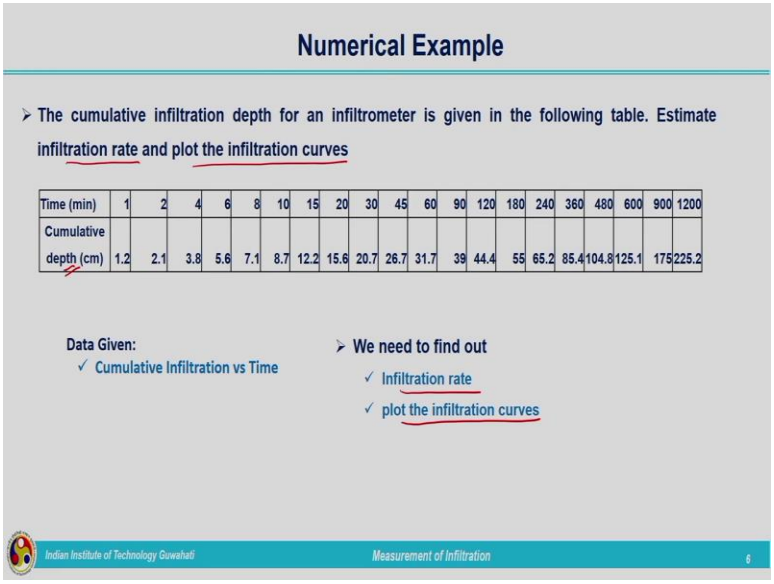

Now, for understanding this process, or for understanding how the infiltration curve will be looking like, we can solve one numerical example. First, let me read out the question.

Q- The cumulative infiltration depth for an infiltrometer is given in the following table. Estimate infiltration rate and plot infiltration curves.

This is a very simple example. The observations from the infiltrometer is given to us. We just have to calculate the infiltration rate and also plot the curves. This is the table corresponding to the infiltrometer data. Time intervals (min) and cumulative depth (cm) are given.
[Note- This is the cumulative depth, it is not the incremental depth].

Now data given is cumulative infiltration versus time, and we need to find out infiltration rate and also plot the infiltration curves. So, two things we have to do. Cumulative infiltration depth is given to us, we need to calculate the infiltration rate, and also two curves, one is the cumulative infiltration curve, that is, direct plotting of these data, and second one is the plotting of the infiltration rate.

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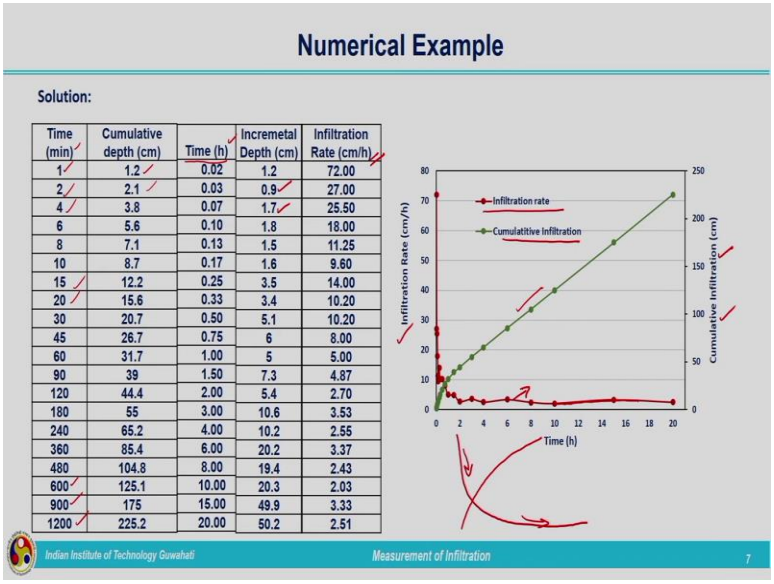

These are the data which are given in question. Time is given in minutes, cumulative infiltration depth in cm. Now, we need to convert the time into hours. There is no issue if you are plotting the graph in minutes, but it is around 1,200 minutes. So, it is better to convert it into hours. So, for that, the time is converted into hours, that is, put in this column.

Now, for calculating the infiltration rate, we need to have the incremental time, time interval with which the infiltration is taking place. So, that we are calculating, the difference between each increment. So, 0.0166 - 0 = 0.0166 h ≈ 0.02 h, 0.033 - 0.017 = 0.016 h ≈ 0.02 h, that way time increment will be calculated.

After that, we will be finding out the corresponding incremental depth, how much is the depth of water infiltrated within each increment of time. Once we divide this incremental depth by this incremental time, we can calculate the infiltration rate. Here the units are, infiltration depth is in cm and time is in h, so infiltration rate will be in cm/h.

Now, we can plot the infiltration rate curve and the cumulative infiltration depth curve. So, when we plot, we can get infiltration rate like this. Initially, high infiltration is there.

Then it comes down, and reaches a steady state value. So, this red curve is representing the infiltration rate. And infiltration rate is marked on the primary y-axis. Along the secondary y-axis, I have marked the cumulative infiltration in cm. And time axis is common to both infiltration rate and cumulative infiltration.

So, this green line is representing the cumulative infiltration curve. So, when you look at the curve, you can understand that it is an increasing curve. That is every interval, the water is getting cumulated, and finally we will get the total amount of water infiltrated into the ground. So, cumulative infiltration curve will always be an increasing curve, and infiltration rate curve will be decreasing, and finally, it will be reaching a steady state value.

What we are doing? We are inserting the rings into the ground, and we will be adding water and record the initial height of the water level. Then we will note the drop in the water level at various time intervals. In the falling head case, we will be considering that. We will be measuring the drop corresponding to a given time interval say, 5 min interval we will be keeping. Initially, it can be taken at 1 min interval, 1, 2, 3 (mins), that way. Later on, once the infiltration rate is reduced, you can continue the experiment or take the readings at a larger interval. And this should be continued until you get a constant rate of infiltration.

Here, you can see, initially measurements were 1, 2, 4, that way. Initially, time increment was low. 1 minute, 2 minutes, then it has increased to 4, 6, 8, 10, then 15, 20, and finally, you can see, 600, 900, 1,200. So, the gap between the time interval is increasing because there is not much changes taking place in the value corresponding to the drop. So, that time, almost the soil is becoming saturated or rate with which the infiltration is taking place will be lowered.

So, depending on that, as time elapses, you can increase the time duration with which the measurements are noted down. And regarding other type of infiltrometers, that is tension infiltrometer, mini disk infiltrometer and flux-based approach, that is, the rainfall

simulator, those things, some of the textbooks are dealing with that. So, as of this syllabus, I am not including that. Conventional methods of measurement of infiltration only incorporated, such as the ring infiltrometers.

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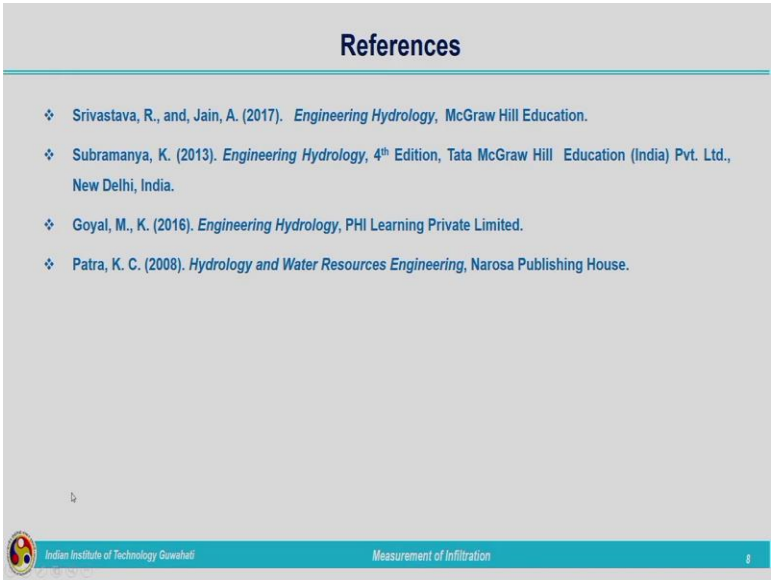

So, these are the references corresponding to this topic. So, here, I am winding up related to measurement of infiltration. Thank you.