Micro Irrigation Engineering
Prof. Kamlesh Narayan Tiwari
Department of Agricultural and Food Engineering
Indian Institute of Technology – Kharagpur

Lecture – 43
Tutorial 8 - Numerical Examples on Sprinkler Irrigation System

Hello, participants. Now, I am starting a new lecture. This Lecture 43 is on tutorial problems. A tutorial is on the topic of sprinkler irrigation system where we have solved some numerical problems. This will give you working experience on how to deal with the sprinkler irrigation system. When one wants to design the system or one wants to layout the system. So, here you are given solved examples on the sprinkler irrigation system.

So, the first problem, it is given here. We are required to determine sprinkler irrigation system capacity to irrigate 10 hectare area of maize crop. The design moisture use rate is 5 millimeter per day. So, this is the water which is being withdrawn from the soil by the crop which is 5 millimeter per day. The field capacity of the soil is 18%, permanent wilting point is 12%. So, soil, these 2 constants are available to us. We are given bulk density of 1.6 gram per cc. Root zone depth is 60 centimeter. This is another depth data available to us. Irrigation efficiency of the system is 70% and irrigation is given 12 days interval in a period of 10 days. The sprinkler system is operated 12 hours per day. So, we are given these data.

Now, these data are kept in a symbolic form. Means, A is the area in 10 hectare. Moisture content at the field capacity is 18%. Moisture content theta pw is 12 percent. Depth of root zone is 60 centimeter. Consumptive use rate that is moisture use rate is 5 millimeter per day. Irrigation efficiency of the system is 70% and the bulk density of the soil is 1.6 gram per cc. 10 days is the period means in 10 days the irrigation is to be given and that is the operating hours of the pump or sprinkler system is 20 hours.

So, irrigation depth can be found out by using this data.

$$Irrigation\ depth(d) = (\theta_{fc} - \theta_{pw})\times\rho_b \times d_{rz}$$

That is the moisture means available moisture content which is the difference in the moisture content that is theta fc minus theta pw multiplied by the bulk density into depth of root zone.

$$Irrigation\ depth(d) = (18\ -\ 12)\times 1.65\times 0.6\ =\ 5.94\ cm$$

So, after substituting these values, we get depth of root zone at 5.94 centimeter. So, this is the depth of irrigation which will be used in the problem. So, system capacity if we are expressing in liter per second,

$$Q\ =\ 2780\frac{A\times d}{F\times H\times E}$$

Where the area is given as 10 hectare. d is the depth of water to be given in 5.94 centimeter and this F is 10 days. H is 20 hours and then E is 70 percent. So, this is in percentage so this will be used as such. So, we are getting this value as 11.80. If the system capacity means our pump should be of this capacity to irrigate the whole crop. This is the solution to that particular problem.

Now, we want to work out second problem. Here we are given means we are given the diameter of nozzles of a sprinkler, so, 3 millimeter and 2.5 millimeter. Mean, this is a twin nozzle system and this sprinkler head or nozzle is operating at 2 kg per square centimeter pressure. And then the coefficient of discharge is 0.96 for the range nozzle and then 0.94 for the spreader nozzle. So, Cd is known to us.

So, once again this data I am reading here, d1 3 millimeter, d2 2.5 millimeter and this is operating pressure is 2 kg per square centimeter which is equivalent to 20 meter of water column. That is 20 means your h and the coefficient of discharge is known to us 0.96 and Cd2 is 0.94. So, area of the range nozzle, by substituting the value of d1 that is 3 millimeter. So, if we are expressing in meter, so, this become 0.003.

And then, we get the value of area of the range nozzle is

$$a_1 = \frac{\pi}{4}\times (d_1)^2 = \frac{\pi}{4}\times (0.003)^2\ =\ 7.07\ \times 10^{-6} m^2$$

So, this is the area of this first nozzle. Then, second nozzle which is of 2.5 millimeter in size. And then, the area will be

$$a_2 = \frac{\pi}{4}\times (d_2)^2 = \frac{\pi}{4}\times (0.025)^2\ =\ 4.9\ \times 10^{-6} m^2$$

In the same way, it is calculated. So, having got this area, we will be just simply substituting the values of a1, a2 and Cd1, Cd2 in this expression.

$$Discharge\ (q) = \left(C_{d1} \times a_1 \times \sqrt{2 \times g \times h}\right) + \left(C_{d2} \times a_2 \times \sqrt{2 \times g \times h}\right)$$

So, discharge q in cubic meter can be written as

$$Discharge\ (q) =$$

$$\left(0.96 \times 7.07 \times 10^{-6} \times \sqrt{2 \times 9.81 \times 20}\right) + \left(0.94 \times 4.9 \times 10^{-6} \times \sqrt{2 \times 9.81 \times 20}\right)$$

$$= 2.25 \times 10^{-4} m^3 s^{-1}$$

So, after substituting these values, we get the total discharge. So, if there are say similar sprinklers and are attached in so many means 10 numbers, 15 numbers, 25 number so, we will get a total discharge. Now, this total discharge from all the sprinklers will be used to find out the discharge from a lateral. Or, if these are the so many number of laterals, so many number, so much of the discharge which is required then we will use this value to find out a system capacity.

Now, this is the Question 3. In Question 3, we have been given data that a spacing of the sprinkler along the main mean this there is a main pipeline, this is your lateral pipeline. Now, the spacing of the lateral, a spacing of the sprinkler, so, this is one is sprinkler. This is another sprinkler. It is given as, so, this is your main pipeline. This is a lateral pipeline. So, we are putting here it is as Lm and this is Ls. Say this is at another sprinkler which is at 12 meter. So, this spacing is along the lateral. So, here, it is given this is 18 meter. This is 12 meter, Ls. So, 18 meter and this is a main pipeline. So, here, the spacing along the main is 18 meter and 12 meter used to irrigate a crop which is grown on a sandy soil and the slope is 3%. The maximum allowable application rate is 3.75 centimeter per hour.

So, slope is known to us, sandy soil is given to us. So, from the table, from the data available we will choose, what is the maximum application rate? So, this information is given to us. That is 3.75 centimeter per hour. Now, another information is given, there are 20 sprinklers which are used. So, there could be you know I can say here say there are 10 sprinkler in this lateral. There are 10 sprinklers in this lateral.

So, total sprinkler, number of sprinkler will be 20. Now, if I have to use this particular main pipeline so, what will be the total discharge that will be carried by the main and this main will be receiving water from the pump. So, this way will be calculating.

So, we are given information. So, Sl that is the spacing along the lateral of means spacing of the sprinkler along the lateral is 12 meter. Sm is 18 meter. Application rate I is 3.75 centimeter per hour or 37.5 millimeter per hour. This can be written. And this is just a simple formula. We can write here.

$$q = \frac{S_l \times S_m \times I}{3600}$$

So, if I substitute the value, we will get discharge from a single sprinkler nozzle. So, I am substituting the value and I am getting the discharge from a single sprinkler nozzle is 2.25 liter per second. So, this total system capacity will be N into q. So, this is a 20 multiplied by 2.25. So, system capacity it becomes 45 liter per second. Now, this is a capacity which is used for the pump to decide that my pump should be able to deliver this much of discharge. So, accordingly, we will choose the pump discharge which will be used and then pump also needs how at what head this will deliver. So, head requirement and that will be used to calculate the horsepower requirement of the pump.

Question 4, in Question 4, it is given a sprinkler irrigation system operates 12 hours per shift. So, this is the one data available to us. And then the 2 shifts per day during peak demand is used in each irrigation cycle of 10 days. So, irrigation cycle is given 7 days means it is weekly irrigation cycle and area is 15 hectare. The gross depth of irrigation is 80 millimeter. Determine the capacity of irrigation system.

So, once again I am reading this data. A sprinkler system is operating 12 hours per shift. 2 shifts are used in a day time. Then, each irrigation cycle is of 7 day. Area is 15 hectare, gross depth of irrigation 80 millimeter. So, we need to determine the capacity of irrigation made by sprinkler system.

So, symbols we have used. If that is area, for area that is 15 hectare. Depth of irrigation d in 80 millimeter, number of shift to irrigation interval that is 7 days and 12 hours per shift it is working. So, irrigation means here this is the area it is in hectare. d, the depth of water application that is in millimeter. So, area in hectare that we can say this is in square meter.

If I am putting depth in mm, then it is divided by 1 by 1000 and area in ha multiplied by 10,000 so, this becomes 10. So, this is the unit constant. And I, since we are interested to express it in per hour, so, I is the number of irrigation cycles in days. This is 2 shifts and then, per shift, it is operating in some certain hour that is 12 hours. So, Q will be calculated by simply substituting these values in this particular formula.

$$Q = \frac{10 \times A \times d}{I \times N_s \times T}$$

$$Q = \frac{10 \times 15 \times 80}{7 \times 2 \times 12} = 71.43\, m^3 h^{-1}$$

That is a 71.43 cubic meter per hour. So, this is a system capacity. System capacity is nothing but the pump capacity. So, pumps should be able to deliver this much 71.43 cubic meter per hour to meet the irrigation requirement of 15 hectare when the depth of irrigation is 80 millimeter and it is operating 12 hours in 7 days period.

Question 5, in this Question 5, we have been given data of 30 liter per second. Now, this is a pump which is delivering discharge of 30 liter per second. And, with this pump, 100 millimeter dia. pipeline of 100 meter is attached. We are required to find out the head loss due to friction using Darcy Weisbach equation. So, we discussed about this equation in the design of sprinkler irrigation system when I discussed and also we discussed this equation when I dealt with design of micro irrigation system. So, in this equation, there are some certain you know Darcy Weisbach equation involves frictional factor. This value of frictional factor is given. This involves a constant c. This involves a constant m. This is involves a constant n.

And also, using Hazen William's equation. So, both the equations which have been discussed in theory class are being here given in the problem. And, in this particular equation, it involves capital C. It is dealing with the pipe material and diameter of the pipeline. So, capital C is given as 140 and then the small c, this particular thing is given and then constant m is 1.852. Constant n in this equation is 1.17.

And then, considering the pipe is running without sprinkler, it is a simple blank pipe. Water is being delivered from one end and then supplied in the lateral and then it is going out of the lateral. Or, this is one case. And then, another case, when the pipe is having 10 number of sprinkler which are equally spaced so, there are 10 number of sprinkler means 10 outlets are provided. The, another part, it is given the distance to first sprinkler is the same as the other sprinkler heads spacing. Means, all the sprinklers are at equal spacing. So, this is the question which is given and then let us try to see solve this problem.

So, once again I am reading the data. Q is 30 liter per second which can be written in terms of cubic meter per second. That is 0.03 cubic meter per second. Diameter of the lateral, 100 millimeter. That is 0.1 meter. And, length of the pipeline is 100 meter. Area simply, pi by 4 D square. So, D is known to us. So, we are getting 7.85 into 10 is to power minus 3. This is the area of the pipeline. And this data, we will be using to find out the velocity of flow.

So, Q is known to us. So, velocity of flow through the pipeline is simply discharge flowing into the pipeline divided by the area will give the value of 3.82 meter per second. This is the velocity of flow through the pipeline. Now, when we use Darcy Weisbach equation,

$$h_f = \frac{f \times L \times v2}{2 \times g \times D} \times F$$

So, Darcy Weisbach equation, it involves the value of f. It involves the L. That is the length of the pipeline. Velocity is known to us. That is we have already got 3.82. g is the acceleration due to gravity. D is the diameter of pipeline which is if we are expressing all in meter means L is in meter. This is also in meter.

When without having any sprinkler attachment, it is a blank pipeline. So, a reduction factor formula is used. Here, in this equation,

$$F = \frac{1}{m+1} + \frac{1}{2N} + \frac{\sqrt{m-1}}{6N^2}$$

This is the reduction factor formula is used. To get the reduction factor value, we are particularly, when the sprinklers are means spacing between the sprinklers are at the same means spacing. So, this formula is applicable. Reduction factor formula is applicable. And the value of m is known to us, for the Darcy Weisbach equation, m is 2. And then, number of outlets, it is a simple one. Means, there is one, water is entering from the inlet and going out. So, it is, there is one outlet. That is N. Capital N is equal to 1. So, simply, we are substituting the value,

$$F = \frac{1}{2+1} + \frac{1}{2(1)} + \frac{\sqrt{2-1}}{6(1)^2} = 1$$

We are getting as 1. We are substituting the frictional factor, length of the pipeline, 100 meter and velocity, already we have calculated, V square is 3.82 square meter. And then, substituting the value of diameter, and then, acceleration due to gravity,

$$h_f = \frac{0.03\times100\times(3.82)2}{2\times9.81\times(0.1)}\times1 = 22.31\, m$$

we get head loss due to friction as 22.31 meter.

With the 10 number of equally spaced sprinklers, the value of F will change. And this value of F here, m is already given to as 1. And then capital N is 10 and then, so, we are substituting in this equation

$$F = \frac{1}{2+1} + \frac{1}{2(10)} + \frac{\sqrt{2-1}}{6(10)^2} = 0.385$$

We get the reduction factor F is 0.385. So, once we substitute the value, the value means this was for one sprinkler. So, I am if I multiply 0.385 multiplied by 22.31, we will get 8.59. Or, simply, I am substituting F, L, V square by 2 g d.

$$h_f = \frac{0.03\times100\times(3.82)2}{2\times9.81\times(0.1)}\times0.385 = 8.59\, m$$

So, once we substitute and multiplied by this reduction factor of 0.385, we get the head loss due to friction by Darcy Weisbach equation is 8.59 meter.

Now, given same problem, but by using the Hazen Williams equation for 100 meter long pipeline which can be given by

$$H_f(100) = K\left(\frac{Q}{C}\right)^{1.852} \times D^{-4.871} \times F$$

Where K is the unit constant and then, Q by C. Q is the discharge. C is the given that is 140 and then, this discharge in liter per second. D is the diameter of pipeline in millimeter and F is the reduction factor. So, this is the equation for 100 meter long pipeline.

So, same thing, when we are calculating the friction factor, a reduction factor by using the Hazen Williams equation here, m is 1.85 plus 1 divided by 1 by 2N. N is the 1 because without sprinkler attachment and simply we are putting this. So, we get the reduction factor F equal to 1. So, if I am calculating head loss from 100 meter pipeline is given by 1.22 into 10 is to power 12 and then Q is already known to us. So, we are substituting the value of Q and then capital C and this D is known to us.

$$H_f(100) = 1.22\times10^{12}\left(\frac{30}{140}\right)^{1.852} \times (100)^{-4.871} \times 1$$

$$= \mathbf{12.75\ m}$$

So, we get 12.75. So, what we see if you just compare the value? If we see here in previous problem we got the without sprinkler the pipeline, this is for when we are considering the per meter pipeline. This is 100 meter pipeline this is coming 22.31 and when we are using the Hazen Williams equation, it is coming 22.75. So, Hazen Williams equation, in this case, what we see? This is means the head loss due to friction by this equation it is underestimating. And when we use this equation for 10 number of equally spaced substituting these values and so, for 10 the difference is only we will be multiplying with the reduction factor. And, this reduction factor in this case is 0.402.

$$H_f(100) = 1.22\times10^{12}\left(\frac{30}{140}\right)^{1.852} \times (100)^{-4.871} \times 0.402$$

$$= \mathbf{5.13\ m}$$

So, we are getting the head loss due to friction is 5.13. So, this in this case also, what we find? The head loss due to friction from this 100 meter pipeline with the 10 number of equally spaced the sprinkler, It is getting 5.13 meter whereas in case of Darcy Weisbach equation, we got 8.59. So, what we find? Darcy Weisbach equation, it is overestimating. Of course, it is overestimating which I can say because the value of F has been considered as a constant which is not constant.

It will change as the number of sprinkler because it is a function of Reynolds number. The small f is a function of Reynolds number. So, f, if I am taking constant, then this kind of situation is existing. Otherwise, the value will be different. But, by considering the same value means constant value of F, we when we are comparing, we get this value. So, we worked out this problem.

Now, in Question 6, we are given a sprinkler irrigation system consists of 2, 186 meter long lateral lines. The spacing between lateral line is 18 meter. And allowing 1 hour for moving, each 186 meter long lateral pipeline. We are required to determine the number of hours required to apply 5 centimeter irrigation in 16 hectare square field. How many days it will take to complete irrigation if the system is operated for 10 hours per day and the required application rate is given to us is 1.25 centimeter per hour.

So, we have been given 2 lateral lines of 186 meter long and then the spacing between the lateral is 18 meter. 1 hour is for shifting these laterals and then we are required to find out, how much time it will take if the irrigation is given 5 centimeter in the area of 16 hectare, 10 hours is operated per day? Application rate is also available.

So, this information is available, application rate is available, field is square. That is your 16 into 10 is to power 4 square meter. And then time of operation is 10 hours per day. So, we will be irrigation time to apply 5 centimeter of depth at the rate of 1.25 centimeter per hour. So, this is coming capital T is 4 hours. Now, time required for moving the lateral is 1 hour.

So, total time for each setting it becomes your 4 plus 1. That is a 5 hours. Now, since, field is 16 hectares, so, 16 into 10 is to power 4. So, we can say it has a length of 400 meter. Means, 400 meter by 400 meter, since, it is a square field. So, it will be 400 meter long 400 meter wide.

The entire field of 400 meter long it is covered by 2, 186 meter laterals. That means 400 meter long where the spacing is given to us it is 18 meter. So, number of moves, it is 22 moves. Means, we will be shifting from one lateral with the, like this, so, which is of 18 meter spacing. So, this way, there will be we can say there will be 22 number of laterals if all the laterals are fixed. But, since movement is made, so, there will be 22 number of moves and then total time required for each irrigation is 22 into 5 and divided by 10. So, because there are 10 days, so, this, we, it will need 11 days. Time required for irrigation is 11 days. We will means total time required to irrigate 16 hectare of the land with the having the 22 number of moves and each moves requires 5 hours and then 10 days. So, 10 hours per day. So, this is we are getting 11 days to cover the 16 hectares of the land.

You please refer these books for to work out more problems related to sprinkler irrigation system.

In order to summarize this lecture, we worked out numerical problems which dealt with capacity of sprinkler irrigation system. We also dealt with the finding out the discharge of individual sprinklers. We dealt with the head loss due to friction in the pipeline of the sprinkler system. And then, the total irrigation time for sprinkler irrigation system. This also we worked out.

In Tutorial 9, we will be working out we will be going deeper having got the experience of these problems. So, we will deal in detail about the design of sprinkler irrigation system with given numerical data as an example. So, thank you very much.