Micro Irrigation Engineering
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Lecture - 44
Tutorial 9 - Numerical Examples on Design of Sprinkler Irrigation System

Welcome, participants of Micro Irrigation Engineering subject. Lecture 44, I have kept it for Tutorial 9 where we are solving problems on design of sprinkler irrigation system. In previous lecture, we discussed numerical problems on sprinkler irrigation system where we solved several problems related to finding out the capacity of the sprinkler system. We also found out, how to find out the head loss due to friction in the main pipeline and sub main pipeline? We also used different equations which were involved in solving the problems related to the parameters of head loss due to friction or even capacity of the sprinkler system and using the data related to irrigation interval and then the time of operation. So, those things we discussed.

Now, having got enough knowledge on the design part. We will use our knowledge for the design of a sprinkler system by taking a hypothetical example. So, the concept here covered is sprinkler irrigation system design.

Now, for a crop here it is given 5 hectare area that is a sugarcane crop. And the field where the sprinkler irrigation system to be installed and designed for this. So, in the 5 hectare area, we have given information that it is a sugarcane crop. And this soil has its texture, its property which is silt loam soil. It has infiltration capacity of 1.25 centimeter per hour. The soil has water holding capacity of 15 centimeter per meter depth of the soil. Root zone depth of the crop is 1.5 meter. Daily consumptive use rate is 6 millimeter per day. Means, every day 6 millimeter of water is used by the crop for meeting the evapotranspiration requirement. And then the sprinkler system, it is a rotating head sprinkler nozzle and there are other data which are available.

We have decided that lateral should be 18 meter spaced along the main. So, practically, it is the sprinkler spacing along the main which is 18 meter. And then, sprinkler spacing along

lateral, it is 12 meter. So, this is the area covered by one sprinkler, 18 meter by 12 meter. Then, the pump is able to deliver pressure of 2.5 kg per square centimeter. So, this is the operating pressure which is required for the sprinkler to operate. That is 2.5 kg per square centimeter. And then, there are 2 nozzles. It is a twin nozzle system. So, one nozzle that is a range nozzle is having size of 5.5563 millimeter. And then, spreader nozzle is 3.175 millimeter. The pump which is used to take water from the well, so, it has got suction lift of 20 meter. The application efficiency of the sprinkler system is 90 %. That is irrigation efficiency, we can say and the system operate till 10 hours per day.

So, these are the data which are available. The other data here, it is given. Difference in the highest point of lateral and main from the pump level is 0.5 meter. So, this is another one data which is available with us. And then, the pressure variation from the main to the farthest point of lateral is 2 meter. So, this is the pressure variation.

Rather, I say it is the elevation difference which means elevation of the farthest point with respect to the main. So, lateral, when we are placing it so, that last sprinkler which is attached with the lateral. And then the first sprinkler which is attached with the lateral which is connected with the main. So, this elevation difference is given as a 2 meter. So, these data we will use while we will solve the problem.

Now, these data in the symbol form it is given. That area is 5 hectare. The water holding capacity which we called as a moisture content at field capacity is 15 centimeter per meter depth of the soil. Depth of root zone of the crop is 1.5 meter. Application rate means we need to operate the sprinkler below the infiltration capacity of the soil. That is 1.25 centimeter. Mean this is the maximum allowable value. If it goes more than this, it will form run off.

So, basic purpose of a sprinkler irrigation system as well as drip irrigation system, we are not allowing the water when we are applying, it should form run off. So, it should be always less than the infiltration capacity of soil. But, application rate it should not be that low that the water should fall and then it will meet the requirement. It should not be that fine drops. That it does not fall, it remain in the air. There will be huge loss of water in the form of evaporation. And then, consumptive use rate of the crop is 6 millimeter per day. So, this is

another data available to us. So, Step 1, we are given maximum application rate of 1.25 centimeter per hour. This is the requirement and total water holding capacity of the soil in the root zone depth of 1.5 meter. So, this is 22.75 centimeter will be the water which will be held in 1.5 meter.

Now, we are assuming here we will allow up to 50 % depletion then irrigation is given. So, when the 50 % depletion it comes, irrigation is given. So, for 50% depletion, the amount of water will be means 50% of 22.5 centimeter that is 11.25 centimeter. Now, assuming the water application rate as 90%, then depth of water to be applied is 12.5 centimeter. So, this will be the depth of water which need to be applied for irrigation so that the 50% of depletion will be maintained.

Now, daily consumptive use rate, we are given 6 millimeter per day. So, one can work out, what will be the irrigation interval? For your information, we are taking here 50% depletion of 22.5 centimeter. Not the value which we have got 12.5. Means exactly the water which will be available, it will be 11.25. So, we are using here 11.25 not 12.5. That is the part which I want to emphasize here to get the irrigation interval.

Now, in 19 days irrigation, we need irrigation interval, we need to apply 12.5 centimeter of water in 5 hectare area. So, operation time of the pump is given 10 hours per day. This is in the question it is given. So, we can work out that what will be the capacity of the system. Means, our pump should deliver how much discharge that will be the area multiplied by the depth of irrigation divided by the number of days multiplied by the number of hours operated in per day and then we have to use appropriate unit. So, 5 hectare, it is 5 into 10 is to power 4. That it becomes in square meter and then, 12.5 centimeter to be converted in the meter. So, this will be divided by 100. Then, 19 days 10 hours, so, 19 into 10 and then it is in second, we are converting. So, we are multiplying with 3,600. Once we calculate this value, we get 0.009 cubic meter per second. So, our pump should be delivering this much rate of water in 19 days period.

Now, in the question, Step 4, we are given the value that the spacing of lateral along the main or spacing of sprinkler also we can say along the main is 18 meter spacing of sprinklers.

Along the lateral is 12 meter this is given. This information is available. Now, we will be using manufacturers chart. So, when we are purchasing deciding the system to be installed. So, normally, people take the local dealer where it is available. And then from the local dealer, such chart is available. Or, from the manufacturer, this chart is available. And, we will use this chart to see that all the data which are given in the field, those data are brought to the user for information. So, this is, we will be using the data. Let me just show you the chart. So, this chart is available here.

So, here there are 2 models and this particular model we are taking. The data it is from the MS NOCIL. This is the company means which I used in my area for using this sprinkler system. So, I got the data from the company. And here we can see in this chart, information is available. What is the nozzle size? And then, what are the operating pressure in this chart? Then, what is the diameter of spray and then discharge? And then, depending on the particular type of arrangement, system we are using it. Means, layout we are using it. So, in the problem, we are given that we have a range nozzle of 5.5563 millimeter. Its spreader nozzle is 3.175 millimeter and operating pressure is given as 2.5 kg per square centimeter. So, this is matching with the required data.

Means, the sprinkler will require 2.5 kg per square centimeter to deliver the discharge. So, for this, 2.47 is closer to 2.5. So, we are taking this particular value. And then at this discharge, this particular model, it is delivering means delivering water and which has the circular pattern of water distribution so the diameter of spray it is a 29.9 meter. And then, at this pressure, and for this nozzle, the discharge, it is delivering discharge of 0.637 liter per second. And then what we are seeing we have been given the spacing of sprinkler along the main. Spacing of sprinklers along the main, it is 18 meter. Along the lateral, it is 12 meter. So, this will be delivering water at the rate of this 1.1 centimeter per hour. So, this is another data which we are getting.

So, this is the manufacturer's chart we are choosing as per the requirement. So, information means we have been given that it should be less than 1.25 centimeter per hour. So, this is less than 1.25 centimeter. Now, it is not too less. So, this is 1.1 which is matching with our requirement. So, these are the data means, we have taken the operating pressure as 1.25 from

the chart. We are getting the application which is less than the maximum allowable application rate. So, this is less than this. And then, diameter of coverage about 30 meter discharge of the nozzle. Just now I told you that 0.637 liter per second which is nothing but 0.637 into 10 is to power minus 3 cubic meter per second. So, this data we have obtained from the chart.

Like this, we can use other data which are more appropriate when we will work out the problem. For this problem I am taking maybe we have got another set of conditions. So, we will take that chart and use it. I am giving here example for nozzle. There could be you know there are several companies in the country. More than 100 companies now on the area in the area of micro irrigation they are operating. So, they have got their own chart. Those who are manufacturing sprinkler irrigation system we can get similar data from them also. So, that was for HP model, this is for LP model. So, like this, there can be some other information so we can get the data.

Now, we had the system capacity. We calculated 0.009 cubic meter per second. And just now which we have got that a sprinkler is delivering 0.637 liter per second. So, from this, we can see that how many number of sprinkler that can be operated from that system capacity. So, what we find, it is the 14.12 or which is equivalent to 14 sprinklers. So, 14 sprinklers can be operated from the required system capacity with which is estimated.

So, these 14 laterals, it can be laid. This is one of the pattern which I am suggesting. There are 2 laterals and in each lateral we are putting 7 number of sprinklers. So, this way we will get what will be the length of the pipeline? So, if I put means it is given in the question that sprinklers are spaced 12 meter and 18 meter apart. So, means, they are spaced 12 meter and on each 2 lateral lines, they are 18 meter apart. So, there are 7 sprinklers and then, each sprinkler has got spacing of 12 meter. So, the length of pipeline is 84 meter. 12 into 7 is 84 meter. And to operate the sprinkler system, it requires a pressure of 2.4 kg per square centimeter. Now, 2.47 kg per square centimeter, here, it is equivalent to 24.7. This is a 24.7 meter. So, the total allowable pressure variation as per the guideline, it is 20%.

So, 20% of 2.47 is 0.494 kg per square centimeter or 4.94 or I can say 20% of 24.7 is 4.94. This is the allowable pressure variation. Now, this allowable pressure variation, it will accommodate whatever the losses in the pressure can take place. So, in the question, it is given. There is a pressure variation due to elevation, it is 2 meter. This is already given in the question which I told you. So, from this 4.94 meter, 2 meter will be used for elevation. So, remaining pressure which is allowable is only 2.94 meter. So, this 2.94 meter is will be considered for estimating the diameter of the pipeline. Means, this will be used for head loss due to friction. Now, to get the discharge from the lateral, so each lateral has got 7 number of sprinklers. So, 7 into 0.637 multiplied by 10 is to power minus 3. So, we are getting 4.459 into 10 is to power minus 3 cubic meter per second. So, this is the discharge of a single lateral. Means, each lateral will be requiring this much of discharge.

Now, head loss due to friction, it can be estimated by Darcy-Weisbach equation. It can be estimated by Hazen-Williams equation. It can be estimated by Scobey formula. Here, we are using Darcy-Weisbach equation. So, Darcy-Weisbach equation, when I am talking, that head loss due to friction is given by

$$H_f = \frac{K \times c \times L \times Q^m}{D^{2m+n}} \times F$$

Where K is a unit constant, c is another constant in this equation and then L is the length of the pipeline in meter and Q is the discharge from the pipeline in liter per minute. And, D is the diameter of the pipeline in millimeter and F is reduction factor. Now, this K is another means this is also another factor. And, this factor is associated with the friction factor, this capital K. So, this capital K is estimated by using this equation which is given by

$$K = \frac{0.811 \times f}{g}$$

Now, this f is a friction factor. This friction factor, f, it is a function of Re that is a Reynolds number. It is a function of Re. So, it is a function of Re when I say, means velocity of flow and means this Reynolds number it is estimated by rho VD by mu. Means we should know, what is the viscosity of the fluid? What is the diameter through which the pipe water will be flowing? And then your velocity of flow, dynamic viscosity and diameter of the pipeline. So, this f is you know we will be using appropriate value of f. One has to compute it by using the Moody diagram and another F is the reduction factor. F, reduction factor for Darcy-Weisbach equation. First of all, this is a general equation when these sprinklers are equally spaced. So,

when they are equally spaced and using the Darcy-Weisbach equation, we are using this expression

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

where m equal to 2 and N, this is equal to number of sprinklers or outlet, this is 7 and we are substituting this. These were m and N values in this one and finding out, what is the value of reduction factor? So, for Darcy-Weisbach equation and for a given number of outlet of 7, so, we are getting the reduction factor F as 0.407. Now, we know that

$$H_f = \frac{K \times c \times L \times Q^m}{D^{2m+n}} \times F$$

So, here, Hf is the head loss due to friction. We have already computed 0.811f by g. g is due to gravity and f we have taken. This is assumed or this is available to us. So, we are not computing by using the Reynolds equation or from the Moody diagram. We are directly giving you this value. One has to find out from the Moody diagram. Means, we have to estimate and get the value of f. So, this f is known to us. That is 0.04, then small c using the SI units. So, this is the 277778 multiplied by the length of the pipeline 84 meter and then, this is in liter per minute. So, liter per minute when we are talking, so, this m equal to 2. So, 4.459 into 60 divided by 9.81 D to the power 5. That is 2m plus n. 2m equal to m equal to 2 and n equal to 1. So, this is D is to power 5. So, we are substituting the value and then we are bringing D is to the power 5 this side and then put bringing 2.94.

$$D^5 = \frac{0.811 \times 0.04 \times 277778 \times 84 \times (4.459 \times 60)^2}{9.81 \times 2.94} \times 0.407$$

So, this particular equation can be written in this form. And, our aim is to find out what will be the appropriate diameter of the lateral pipeline to have the head loss due to friction of 2.94 meter having given these data. So, we estimated and found that this is coming as 59.79 millimeter. Now, in the market, these pipes are available in different diameters. But, it cannot be any odd number. They are of standard size. So, it could be 1 inch (means 25 millimeter). Then, it is given as 37 millimeter (one and a half inch). Or, it is 2 inch (50 millimeter). Then, 2.5 inch (63 millimeter). So, this is 63 millimeter from there we have got and which is available in the market.

Now, we will estimate the head loss due to friction in the main pipeline because lateral is attached directly with the main pipeline. So, total length of the main, it is between you know

there are 2 sprinkler lines are attached which are of 18 meter spacing. So, this 36 meter is the length of the main pipeline. Now, head required to operate laterals which are connected with the main pipeline. So, we have been given H naught that it is 24.7 from the chart we are calculating. Now, head loss due to friction, this already we used. That is 4.94. From there, we subtracted 2 meter. So, we got 2.94. So, head loss due to friction in the lateral pipeline is 2.94 meter. This is the head due to elevation. So, this also we will be accommodating and Hr is the height of the riser pipeline.

So, when we are substituting this value, we are getting the total head required to operate the lateral pipe on the main to operate lateral, so, 30.6 meter. Now, again you know we are taking the thumb rule or guideline that the head loss due to friction or total pressure variation, it should not exceed more than 20%. So, we are considering 20% of 30.6. So, 6.12 meter. So, with 6.12 meter as a head loss due to friction, we are computing the diameter of the main pipeline. So, same way, the way we did for lateral pipeline, we are getting the diameter of main pipeline which is 75 millimeter. So, 69.9 is estimated value. But, in the market, 75 millimeter pipeline is available. So, we are considering the diameter of main pipeline. For this purpose is 75 millimeter.

Now, total design head, we will work out in the same manner that we have been given this your total design head Ht equal to Hm plus Hfl plus Hj plus Hs. What is Hj? That is the difference in the highest point of the lateral and from pump is 0.5 meter. This information is already available in the question. We have been also given suction lift of 20 meter. So, we are substituting the values, we have already got head required at the main to operate later is 30.6. Head loss due to friction of the main pipeline is 6.12 meter. 0.5 meter is Hj and Hs is this. So, total head is 57.22 meter. Now, the pump has to deliver 0.0009 cubic meter per second of water against the head of 57.22. So, we can work out the horsepower.

The pump is directly coupled with the motor. It is directly coupled with the prime mover. So, it is the only pump efficiency we are considering. So, let us say that the pump efficiency is 60%. So, the power requirement in kilowatt can be given by

$$pump\ (kW) = \frac{9.8 \times Q \times H_t}{E_p}$$

This is small Ht. So, this is same Ht we are using here and this is the pump efficiency. So, we substitute the value, we are getting 8.41 kilowatt is required which is equivalent in terms of horsepower of the pump which is equivalent to 11.27. 8.41 divided by 0.746. So, 11.27 horsepower of the pump is required to operate the system.

So, now, the, we have worked out the all these components. So, these values are that we have been given the sprinkler nozzle. So, this already we know. We estimated number of sprinklers can be operated 14 and total length of the lateral pipeline, 84 into 2. That is 168 meter. And then the diameter of lateral pipeline is 63 millimeter. Length of main pipeline is 36 meter which is of 75 millimeter diameter and the pump size is 11.27.

So, we worked out one example. It can be another condition and that will the length of the pipeline and then horsepower requirement that can be used. Having given such information for any study area one can work out exactly all the requirement of the distribution network and as well as horse power requirement of the pump can be estimated for given information on soil, for given information on the crop that how much is the water consumptive used rate is there. What is the type of soil? And then, all other information which I explained here if it is available, one can calculate the horsepower requirement. And then, system can be laid in the field.

So, for more problems and your practice, you can refer these books.

So, let us summarize that yes we worked out sprinkler irrigation system design numerical problem and this has given you the knowledge and then, for practice, you can use some other problems of similar nature. In the forthcoming class, we will discuss about having got the design data, how to make the layout? How to install the system? And then, what are the operation and maintenance to be done? So, in forthcoming class, we will discuss on this part. Thank you very much.