Micro Irrigation Engineering

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Lecture - 27
Numerical Example on Design of Drip Irrigation System

Dear participants of this course on micro irrigation engineering, now I am inviting you to lecture 27. Lecture 27 is dealt with tutorial class 5. This tutorial class is on the design of a drip irrigation system. We have given the theoretical aspect of the design of the drip irrigation system. So here numerical problem and then how drip irrigation system design can be made by a given set of data.

So a question is given here for the design of a drip irrigation system which is to be done for a citrus crop of a 1-hectare orchard area with a length and breadth of 100 meter each. This crop has been planted at a spacing of 5 meter by 5.5 meter and pan evaporimeter data will be used to estimate the water requirement of the crop. So pan data is given. This is during the summer month. This is during the peak demand period.

So value is given as 8 millimeter per day. There are other relevant data to this problem. The system is to be laid on sloping land and then the slope has been provided in the upward direction from south to north direction. The water source is located at a southwest corner of the field and it is a well. Soil is sandy loam in texture and content of different proportions of clay, silt, and sand these are also given.

Field capacity is 14.9%. Wilting point is 8%. The bulk density of the soil is 1.44 gram per cubic centimeter. The effective root zone depth is 120 centimeter. And from crop point of view, the area to be wetted by drip emitter is 40% that is the percentage of wetted area. The pan coefficient is 0.7. Crop coefficient 0.8. And then static water level, static water head that is 10 meter. And pump discharge is 2.5 liter per second. So these are the data which are relevant to this particular field. Maybe some data we will need at the time of design. So we need to assume which will be relevant to this particular situation.

So when we come to the solution the first most point to be considered is an estimation of the water requirement of the crop. So we will be estimating the ETc of the crop and this ETc is nothing but the evapotranspiration requirement of citrus crop which can be estimated from the pan data. So we have been given the value of evaporation from the open pan that is 8 mm, pan coefficient is 0.7, and then crop coefficient is 0.8.

And if we multiply all these parameters, then one can get ETc in millimeter per day. This ETc in millimeter per day can be converted to a liter per day if we multiply with the area of each individual plant. But in drip irrigation system, we are not wetting the entire area. So area that we will multiply with the percent wetted area. So the area covered by each plant is 5 m into 5.5 m and the percentage wetted area is also given to us.

That is 40% or 0.4 and then the evapotranspiration requirement of the crop which we have calculated as 4.48 mm per day. So this is equivalent to when we are multiplying this we will get in cubic meter per day. So this cubic meter per day is converted in the form of a liter per day. So which is coming as 49.28 liter per day or 50 liter per day. So this way we will get for each plant, we need to supply water of 50 liter per day.

Now, this 50 liter per day is to be given water with the help of a drip emitter. So it comes for the selection of appropriate size of the drip emitter and this will be selected based on considering the soil texture. So, soil is sandy loam. Crop root zone system means up to what depth the water is going. So this information is also given. This is a crop which is a deep-rooted crop, 1.2 meter.

And then, so considering if we are giving a dripper of the 4 liter per hour and since water requirement is large, this 50 liter per day. So one dripper will not be enough, but we have to provide a sufficient number of drippers and then this water is to be given in this flow rate that this is the characteristic so that the wetting can be made.

So we have selected three drippers which are placed in a triangular system or triangular pattern so that the effective root zone area of the crop can be wetted. So three drippers of 4 liter per hour will deliver in 1 hour 12 liter of water. So this 12 liter of water when it is supplied, will require 4 hours 10 minutes to give 50 liter of water.

So means one plant or all number of plants, each plant which are coming in the one-hectare area, we have to operate the drip system for 4 hours 10 minutes. This is one of the important information which we have generated when we are considering three drippers of 4 liter per hour.

Now in the question, it is given the well is located at the southwest corner of the field. So this is the thing that somewhere the field means well is located at the southwest corner. So this is a pump house and then water is pumped by using a pump. And then we are connecting with the help of a pump, drip system.

So the from the pump water is taken to the filter and then here there will be all control head assembly will be installed means a filter, a fertigation unit all that it will be installed there. And from there we are connecting the main pipeline. So, it is coming to the main pipeline and we are bringing this main pipeline is 50 meter.

Now here this is one of the layouts it can be made in otherwise also it would have been taken from your main goes here and then you are connecting main up to bring it up to this place and then sub-main can be brought. So it is the arrangement one has to see where the minimum size means the length of the pipeline is adjusted so that the cost does not go high.

At the same time, one has to see that energy used for making such pipeline arrangement, it is minimum energy is consumed so that the pump can be also of a smaller size. So this is one of the arrangements which has been considered in the present design. And so after the main is brought up to the center and then the sub-main pipeline is attached. So sub-main can be laid from the center of the field.

So this is your sub-main part, which is connected from the main pipeline and then it goes up to the 97.25 meter of the length of the field. So, 97 we are not taking up to the end of the field means we are able to reduce means 2.75 meter length. Because the plant part of the area is when we are adjusting considering the spacing between the roots. And then lateral are laid on both the sides.

So means, the one lateral you can see on either side of the sub-main pipeline, laterals have been attached. So when we are making the length you can see here the main pipeline is 50 m, the sub-main pipeline is 97.25 m, and then the lateral is 47.5 m. So this way, we are making the layout, and then because the size of the field is known, so we know what will be the length of these pipelines.

Now laterals are connected on both sides of the sub-main. This is the way one can do and reduce the length so that the emission uniformity can be maintained. If the length of the pipeline is very large, then with the means when you are delivering the water so discharge is decreasing with the space. This is especially varied flow with decreasing discharge problem.

So when the water is being delivered, there will be more head loss and then it may happen that the emission uniformity may be reduced means water is coming out of these drippers it may not get adequate pressure at the end. So it is better to have a shorter length of the pipeline. So up to 100 m, there is as such no problem.

But if we reduce the length of the pipeline, we will get better uniformity of water application. So this way each lateral when we are giving that each lateral will provide water to 10 number of citrus plants.

So this way we are getting the number of plants which can be irrigated with the help of drip. Now we will work out what is the discharge through each lateral. So first of all let us try to know that what is the discharge through each lateral. So first we will calculate the number of lateral. So a number of lateral is given by, 100 m is the width of the field. Let us see that once again the layout. So the layout it says that you can see here the 5 m is the spacing between the plants and 5.5 m is the spacing between the rows. So this 5.5 m which has been used that will decide that how many number of laterals will be coming in 100 m long field. So this is coming that 18 number of laterals will be required. So total number of laterals because it is on both the sides.

So on one side, it was 18. So both the sides, it will be 2 into 18 that a 36 number of laterals. Now, we found out there will be 10 number of plants on each lateral. So discharge carried by each lateral is, because there are three emitters of 4 liter per hour that is given to each plant. So there are 10 plants. So, discharge carried by each lateral is 10 into 12 that is 120 liter per hour, which is equal to 0.33 liter per second. So per hour is changed to per second.

Now we will also know that what is the total discharge of 36 laterals. So total discharge by carried out by the 36 lateral is 120 into 36. So this is coming as 4320 liter per hour which is equivalent to 1.22 liter per second.

So this way one can get the discharge of 36 lateral. Now each plant is provided with three emitters. So, therefore, the number of emitters will be 36 into 10 into 3. So 1080 this is another important information which we are getting. So for the one-hectare area, the total number of drippers are 1080.

Now we have been given discharge of a pump as 2.5 liter per second. This data will be used to find out how many sub-main manifolds are required. So if we take the discharge of the pump as 2.5 liter per second, this is equal to 9000 liter per hour. So the number of laterals that can be operated by each manifold. So we have got if you once again see the previous part that we have got 120 liter per hour is the discharge carried by each lateral. So we will be getting that how many number of laterals that can be operated with the given pump discharge. So this is given as we are getting 75. So the pump which is available with us is able to meet the requirement of 75 number of laterals.

So means this one manifold is enough, rather more than enough I will say that will meet the water supply to all the laterals at a time. Now having given this data which we have worked out we will now find out the size of the lateral. So once the discharge carried by each lateral is known, then the size of lateral can be determined by estimating the head loss due to friction.

And this could be estimated by any one of the equations. So one means it could be by Hazen-Williams equation or by Darcy-Weisbach equation. These two equations are commonly used. So this head loss due to friction from 100 m long pipeline using Hazen-Williams equation can be given by

$$H_f(100) = 1.22 \times 10^{12} \frac{(Q/C)^{1.852}}{(D)^{4.871}} \times \mathrm{F}$$

So Q is the discharge, C is a constant that depends on the type of pipe material. The value of C, changes with the type of pipe material as well as the size of the pipeline, means the diameter of the pipeline. And then D is another part that is the diameter of the pipeline, and F refers to the reduction factor. So we will be substituting the value and having the appropriate units of these as it is given in the constant. So we will use the value.

So first let us work out the reduction factor. Here reduction factor is due to the number of outlets provided in the lateral pipeline. So the number of outlets, we know there is 10 number of plants in each lateral and in 10 number of plants, for each plant, there are three drippers. So the number of outlets this is equal to the 30. And then we have the value this is

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

This m is the constant which is used in the Hazen-Williams equation. So m value will be used and capital N is the number of outlets. So we are substituting the value of m, and capital N, and then the value of the reduction factor is estimated and this value is coming as 0.367.

Now head loss due to friction in 100 m pipeline we are substituting the value of Q and then C that is a capital C. So this is in liter per second means Q is in liter per second. Capital C is 130. And then the diameter of the pipeline is assumed as if we are using 12 mm size that is the diameter of the pipeline and 0.367 is the reduction factor.

So we are getting the value of head loss due to friction from 100 meter pipeline is 0.54. Now in the actual field situation in our problem, we know that the length of the lateral pipeline is 47.5 m. So we will work out for 47.5 m, what will be the equivalent head loss due to friction in the lateral pipeline.

So equivalent head loss due to friction in the lateral pipeline when we are multiplying with this 47.5 divided by 100 with 0.54, we get the value as 0.26 m. So permissible head loss due to friction is 10% of 10 m. That is the head required to operate the dripper which is delivering 4 liter per hour. So, therefore, 12 mm pipeline which has been selected is adequate. So this is the one part that is this pipeline of 12 mm is adequate to use the design part.

Now we are coming to the discharge from the sub-main pipeline and as well as selecting the head loss due to friction for finding out the size of the sub-main pipeline. So total discharge from a sub-main pipeline is the number of laterals multiplied by discharge from a single lateral. So the number of laterals, there are 36 laterals. And then discharge of each lateral is 120 liter per hour.

So this is coming to 4300 liter per hour, which is equivalent to which is equal to 1.2 liter per second. Now if we assume the diameter of the sub-main pipeline is 50 mm. If capital D is assumed as 50 mm, the value of the parameter of the Hazen-Williams equation we because the pipe size it is not the same material, we used capital C as 130 for lateral which is of LLDPE material, linear low-density polyethylene.

Here the pipe material could be another you know it could be PVC, it can be HDPE. So the value of C is 150. Q is known that is 1.2 liter per second. The diameter of the sub-main pipeline is assumed as 50 mm. And this is the unit constant that is 1.22 into 10 is to power 12. And F has been calculated by using the same reduction factor formula.

So here we are substituting the value of F, which is coming for the 36 number of laterals. This is 36 number of laterals. So N is 36 number of laterals here, so we will multiply with 2 means we will get the expression for 36 number of lateral head 0.364. So head loss due to friction from 100 m sub-main pipeline when we are substituting the value we are getting 0.31 m for 100 m pipeline.

Now since this pipeline is of 97.25 meter, so accordingly the value of the head loss due to friction is 0.30 m. Instead of 0.31 now it is 0.30 m. So the frictional head loss in the sub-main pipeline is 0.30 m. So head required at the inlet of the sub-main pipeline, which will supply water to the lateral pipeline. So we will know that what is the total head required. So this is coming as the head required to operate the emitter is 10 m.

Head required Hf of lateral, this we have calculated, that is head loss due to friction in the lateral pipeline is 0.26 m. And the head loss due to friction in the sub-main pipeline is 0.30. The slope is, if you see the field, let me just show you once again the layout. So the slope is in this direction means from south to north direction. And it is coming up to 97.25 m in the length.

So it is almost 0.4 m in the length. So this which we are getting here. So what we are seeing here the slope is 0.4 m. So total head loss at the inlet of the sub-main pipeline is 10.96 m. Now let us try to know that how much pressure variation it can have. So when we are getting the pressure variation, what we are doing here we have got 10.96 and then 10.26. So 10.96 minus 10.26 divided by 10.96. So if you work out you will get the pressure head variation is 6.38%. So, 6.38% is very less value, which is coming here.

So we can see whether can we go far lower size pipeline so that we can reduce the cost. So estimated head loss due to friction in the sub-main pipeline is lesser than the recommended 20% variation. Hence, we are reducing the size of the pipeline from 50 mm to 35 millimeter. So when we take this lower size pipeline means 50 to 35 millimeter, we get head loss due to friction as 1.75 meter.

So Hf for 97.25 m will be 1.70. Now we will work out when we have reduced the pipe size what is the value of the head requirement at the inlet of the sub-main. So initially we were getting 10.26, it is now 12.36. Let us know that how much is the pressure variation we are getting. So now we are getting 17% pressure variation. This is also within the permissible limit. So we can reduce the cost of the sub-main pipeline if we go for 35 mm pipe size.

Now we will work out the size of the main pipeline. So here we are considering the size of the main pipeline as 50 mm and then we are considering the same Hazen-Williams equation and because there is only one sub-main, which is receiving water from the main. So here except diameter, the rest of the parameters are the same. So we are assuming the diameter as 50 mm.

The rest of the parameter means C because it is made up of the same plastic material HDPE. C is taken as 150. And Q is equal to 1.2 liter per second. D is 50 mm and K is the unit constant. So we are substituting and we get the value for 50 mm pipeline, which is 0.84 m when the pipe size is of 100 m. Now, this is 50 m. So half of this will be the head loss due to friction that is 0.42 m. So pressure head variation lies within the 20% of 12.36. So we accept this value of the pipeline size that is 50 m pipe of 50 mm diameter is giving the head loss due to friction of 0.42 m. So this is acceptable.

Now we will work out what should be the horsepower requirement of the pump to supply water in drippers in all the laterals. So here assuming the head variation due to uneven field and the losses due to pump fitting as 10% of other losses. So means, this is known as a local loss that is 10% of all the other values.

So we are substituting the value, which means, H emitter that is head required to operate the emitter is 10 m. We have got the Hf value of the lateral that we have calculated. We know the slope of the field. We know the head loss due to friction in the pipeline. So all these things are equal to 12.36 m. And Hf from the main field is 0.42. And then 10 m is the head it is given. And 1.28 is all the losses. So we get 24.06.

Now horsepower requirement can be calculated by using the expression as the total dynamic head H which is here all these components which are explained here that is the head required at the inlet of the sub-main pipeline is 12.36 plus head loss due to friction in the main pipeline plus H static plus H local.

So this is 24.6 in meter and then discharge in liter per second. So this value we have is 1.2 liter per second. So 1.2 is the discharge and 24.06 is the head divided by 75 into pump efficiency which is assumed as 60%. So, we are getting the horsepower requirement is 0.64. So available size in the market is 1 HP which is enough to irrigate the whole field.

So one horsepower pump is adequate for operating the drip system to irrigate a 1-hectare area of citrus crop. In fact, it can meet the essential other requirements also this pump can take care when the requirement of the additional area because it is giving the pump, is of higher size.

So these are all the design calculations which we have got. We have taken the emitter of 4 liter per hour and then the total number of the emitter will be required in 1080. The length of one lateral is 47.5 and then the total number of lateral will be 36. So one can calculate the, what is total length of lateral pipeline which will be needed.

So 36 into 47.5 will give us the total length of the lateral which is 12 mm in diameter. So the length of the sub-main means length of the sub-main is 97.25 m, which is of 35 mm in dia. And then the length of the main pipeline is 50 m which is 50 mm in diameter. And then the horsepower requirement of the pump is 1 hp.

So like this, you know similar other problem you can work out by referring the books which are given in these references.

Let us summarize this particular lecture. We worked out the design of the drip irrigation system by taking one numerical example. Like this, you know this is a wide-spacing crop. And the similar kind of problem can be worked out for the close-growing horticultural crops like vegetable crops which are of close-growing crops where the spacing is less perhaps, which will require more you know discharge.

It will require more number of drippers. It will require more length of the pipeline. So there you can have the optimization. And problem how to get the best layout where horsepower requirement, as well as the total energy requirement, can be reduced. Now forthcoming lecture it will be dealt on fertigation lecture we will discuss in the coming class. So thank you very much.