Water Supply Engineering
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Lecture-43
Water Distribution Networks

Welcome back friends. This week we have started discussing about the water distribution system and in the last class we discussed some brief and basics about the water distribution system. So, this class we are going to talk about the Water Distribution Network and what exactly we are going to cover is the layout of water distribution networks.

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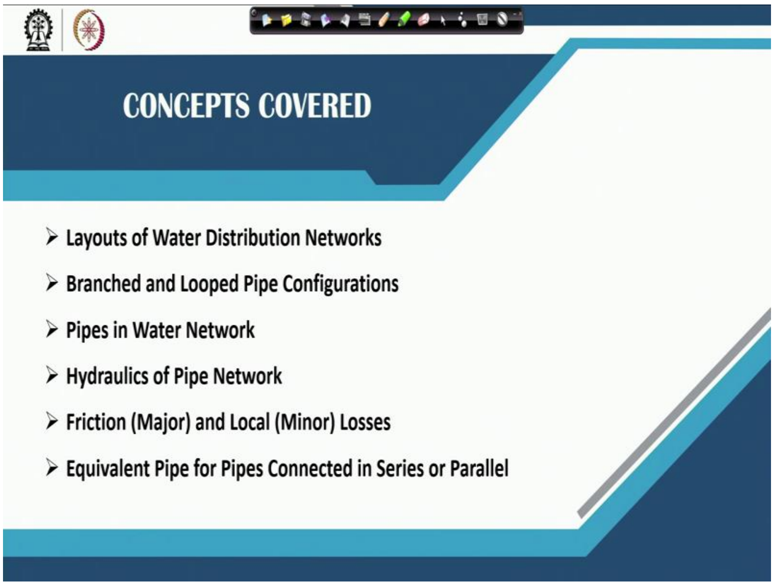

What are the different types of layouts that are placed in the field? We will be talking about specifically branched and looped pipe network configuration. Then I will be discussing about the various pipes that are used in the water network, we will talk about the hydraulics of pipe network. Then we will talk about the losses that happen during the flow including the major that is, friction losses and minor losses which are generally of local nature.

And we will discuss about the equivalent pipe for when there are more than one pipe is connected in series or in parallel so that we are going to cover in this particular class.

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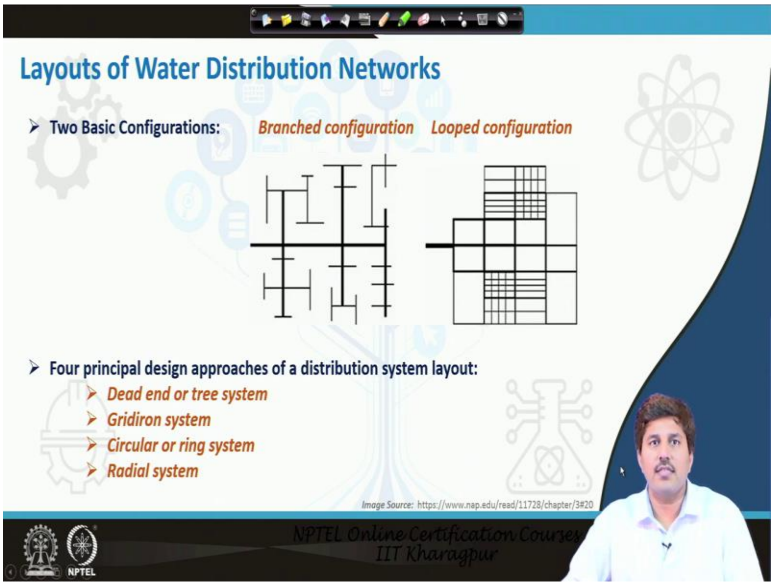

The distribution networks which are laid basically follow 2 configurations so that they will be branched configuration or Looped configuration. The branched configuration is essentially when there is one it is kind of a tree kind of system. We have a tree and then from there are the branches come up and then there would be several dead ends. So essentially it forms a dead end or type system whereas looped configuration is when the pipes are connected in a loop so it be gridiron system, it would be circular or ring system. It could be radial system so that the different type of configurations that are used.

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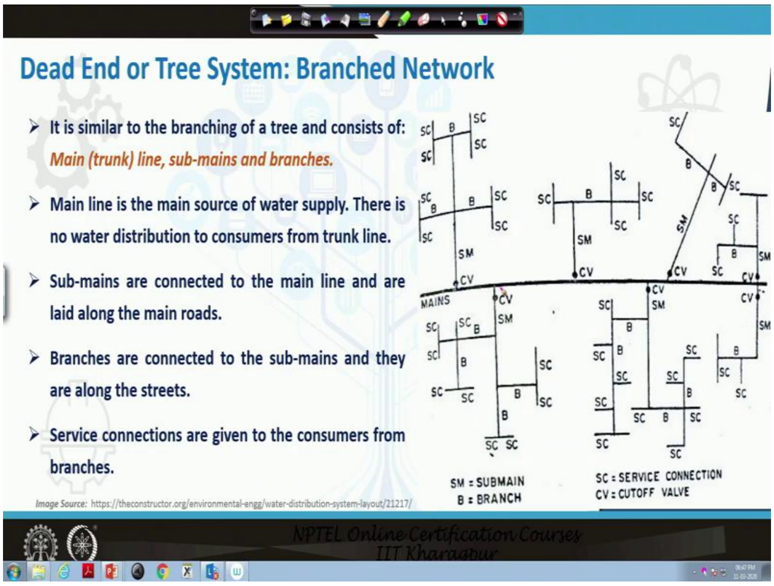

Now, the branched network which is dead end or tree system is essentially a system where we have mains and from mains there are some several sub mains connected. So like from mains, we will be getting pipes which will be the sub mains and then from sub mains we get the branches. The main line is the main source of water supply and there is no direct distribution from the main line. Distribution is sensory takes place from the branches, ok.

The service connection will be basically coming from the branches. So will see a branch and then there will be several service connection from the branches where as the mains does not distribute any water except in emergency and it rather supplies the water to sub mains, various sub mains and then, branches arising from the various sub mains. So, sub mains will be connected to the main lines and are laid usually along the main roads.

And branches are connected to the sub mains and they are basically along the various Streets. Service connections are usually given to consumer from these branches so, that is what is the branched network. Now, this branch type of network has several advantages and disadvantages.

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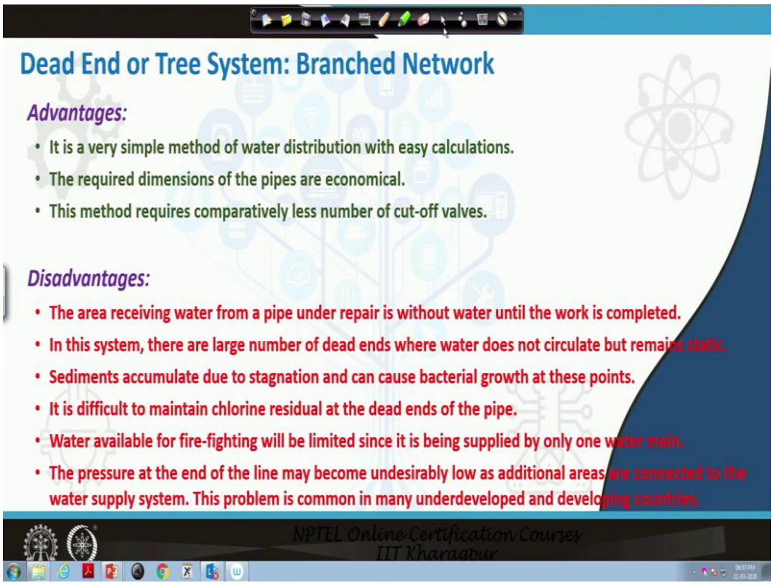

Major advantage is the simple method and water distribution calculations are very easy because we can just sum up the discharge. So, like if a branched network is a feeling several service connections, so the water requirement and the several service connection has to be provided from that branch. Now, let us say if one sub main is feeding several branches so then, the requirement for each branch has to be summed up and that much must be the flow in the sub mains.

And similarly the sum of the various discharge required in various sub mains will be the flow design flow for the mains. So that is how we basically the calculations are very simple, we can compute the dimensions easily and generally the types are economical because one particular connection is designed to carry the amount which is needed at the downstream.

So, let us see if we have this if we have a mains this is now, this mains will be carrying only the amount like mains is fine. But from main slits we get a some sub mains, these sub mains will not be responsible for carrying any discharge anywhere if the target area for sub mains is this, this sub main is carrying only for demand from this area. So, the size of sub mains will not depend on the entire city or will not depend on other places, it will just depends on the demand coming from this section.

Similarly, from sub main if you have branches let us say and the branch coverage is this much so this particular branch will carry the discharge only for this part and not for the other parts. So, that way pipes are generally very economical. This method requires comparatively less number of cut off walls because we can one particular line is targeted at one particular area say if you want to cut off and just put let us say cut off on sub mains and this thing then we do not need several cut off that way.

Inspite, there are various disadvantages as well. The major disadvantage is that because one connection is being fed with just one line. Just say if there is some repair work going on here, if there is some repair work going on here so connection in the all the downstream will be cut off. There will not be any supply in the downstream because all the supplies connected to these sub mains only and if something goes under the repair all subsequent connections will be basically stops.

There will not be any water until the work is completed. There are the large numbers of dead ends in the system where water does not circulate and remain static. Water can actually be stagnant there and there might be possibility of sedimentary accumulation due to this stagnation and there is bacterial growth at these points also possible. This can be overcome if we kind of foot of flushing system.

So, if there is stagnant water in certain branch, we flush out that branch completely so that the sediments or any sort of microbial growth is washed away. But again, causes huge loss of water. Further, it is difficult to maintain the chlorine residual at the dead end of the pipe because the distance might be more of the time that requires so it might like, the chlorine might get in that particular time.

Water for fire fighting will be limited because let us say, if you are having connection where they say this is sub mains and this is basically supplying branches. Now, if you broke off fire here, this might get supply only through this branch. And the since the capacity or dia of this branch will be limited so it can actually may not provide adequate quantity of water required state of flow for fire fighting purpose.

Then, the pressure at the end of the line may become undesirably low because water has been taken from different places during the process and let us say if you are getting a Sub main from here, one branch is going here, one branch is going here, one branch is going here, one branch is going here, so maybe like this will take away some water and then pressure drop will be there. This is will take away so, there will be for the pressure drops.

By the time water reaches towards the last transmission that there is basically substantial pressure drop. So that kind of problem may happen in this is a very common problem particularly in the under developed and developing countries where the branched network are placed.

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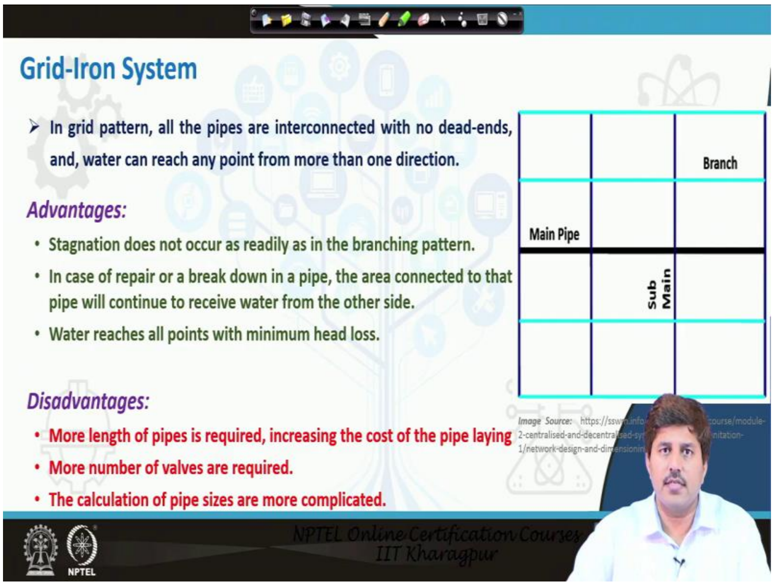

Then, there are Grid Iron systems; the Grid Iron systems actually supply water in a grid pattern. All the pipes are interconnected. There is no dead end in the system and water can reach any point from more than one direction. If you are looking at a Grid Iron Systems will have a mains and then from mains we will get basically sub mains and from sub mains there will be branches but all this system is interconnected. So, there is no stagnation that will happen ok.

In case of repair, let us say if you start preparing this pipe connections water may be circulated from this and water may be circulated from this till this point. So, basically each area gets water from more than one direction so that way like, in case of failure or breakdown, still the community will continue to receive the water from the other side. Water reaches all points with minimum head loss; it is interconnected system for head loss is also less.

On the disadvantage side there will be more length required and that will basically increase the cost of pipe lying, there would be more number of walls required and calculation of pipe sizes becomes much more complicated because the discharge is from the multi direction in the system.

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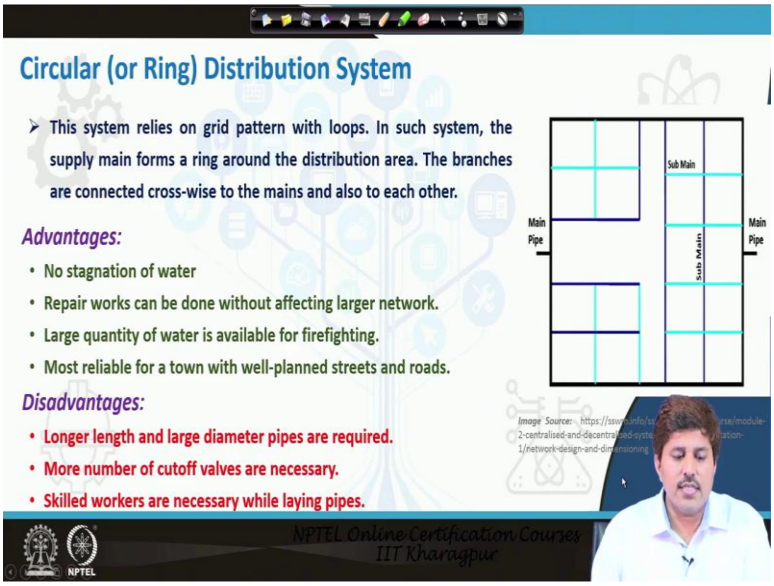

There is another similar system which is circular or ring distribution system, which is basically relies on the grid pattern where loops are made. So, in this system, the main supply is like the main is actually in the form of ring outer ring. So you will see that main pipe is actually in the in the basically outer area outer periphery area of the network that you want to feed in and from there. You will be getting some mains and branches.

So, in this kind of system there would be basically branches of course connected crosswise, but we can focus on one particular area where more discharge is needed. That kind of development is also possible in here. Advantages and disadvantages more or less remains similar to the, the looped system. So there would be no stagnation of water, repair work can be done without affecting the largest network, for fire fighting we can get substantial quantity of water.

And for particularly it is more reliable for towns which are well planned Street and roads because we can say that we are the densities higher, where the density is there lower so, we can basically layout our sub mains or other systems accordingly. On the disadvantage side, of course longer length and larger diameter pipes should be required for system would be costly. There would be more number of cut off walls and it may need skilled workers falling the pipeline all those kind of systems.

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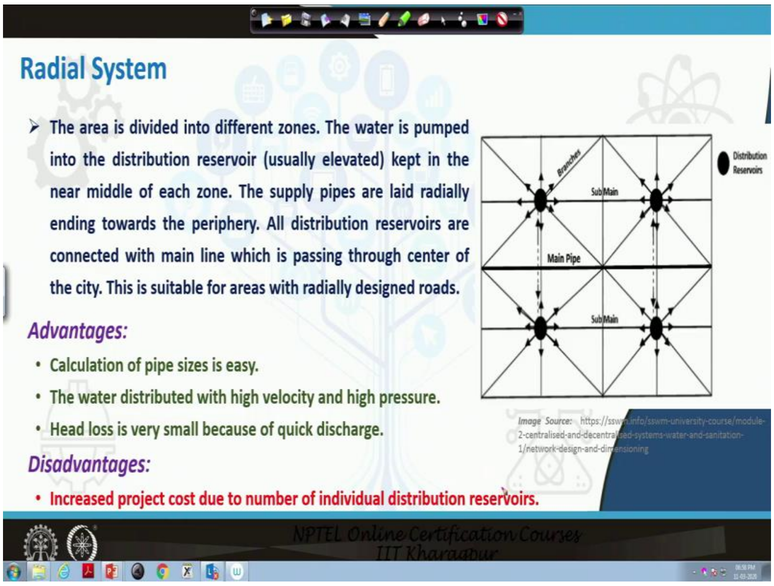

Then another system is the Radial system. So in the radial System India is divided into different zones and water is pumped into distribution reservoirs. We will have several Distribution Reservoirs and distribution Reservoir will have a marked area. So water will be pumped to the distribution Reservoir and then radial lines basically have branches which will be basically covering the entire area.

So, supply pipes lines will be laid radially towards the Periphery from the centre. All distribution reservoirs are usually connected with the main line. So, the passing through the centre of the city which generally passes through the centre of the city so that the from the mains, the distance of the distribution reservoirs is minimised. This is suitable for areas with radially design road and there it can work very well.

The calculation of pipe sizes are relatively easy as the water distribute generally high high velocity and high pressure and head loss is very small because the like from this point distances are very low. It is not covering the entire part so one distribution Reservoir is covering a one area in the nearby and that way head losses are low. On the disadvantages side, there may be Cost increased because we need to place number of individuals reservoirs in the in the region.

If one reservoir covers certain area and for the largest cities we may need to place several the number of reservoirs and that would essentially increase the cost of the project.

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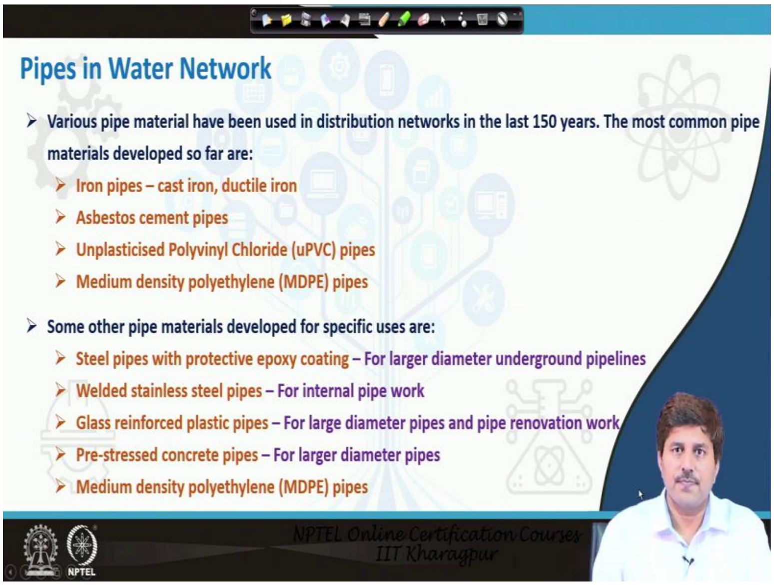

Pipes that we typically used in laying this network is usually made of various materials that has been basically be last 150 year several materials has been tried and tested. The most common materials that include iron pipes which are basically cast iron or ductile iron so CID pipe generally. Asbestos cement pipes are also popular for larger discharge then unplasticized polyvinyl chloride, so generally PVC pipes and the medium density polyethylene MDPE pipe are generally the more common pipes.

There are other pipe materials which are developed for specific use in water supply network steel pipes with tractor epoxy coating for larger diameter underground pipelines it is used. Welded stainless steel pipes for internal pipe fitting work, it may be used then glass reinforced plastic pipes again for larger diameter Pipe and pipe renovation was this kind of pipes may be used. Medium density polyethylene, so similar MDPE pipes may also be used some specific function and then Pre-stressed concrete pipes are generally for larger pipe diameter.

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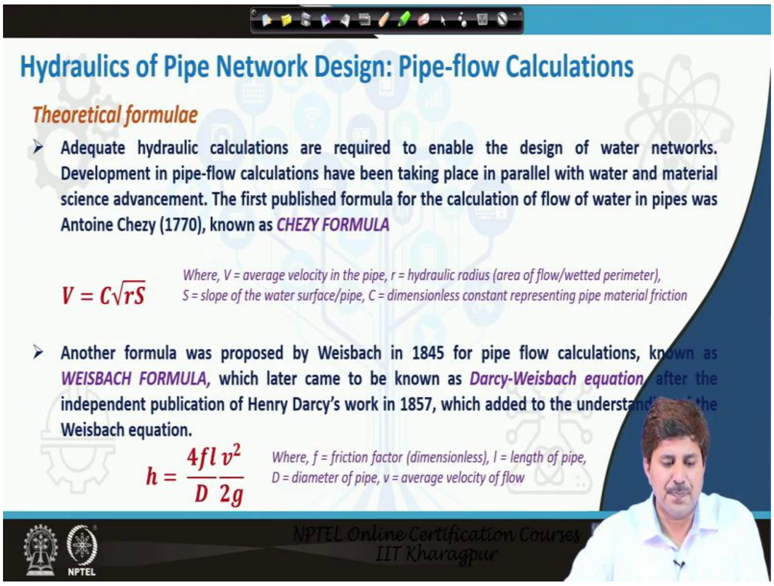

So, for supply to large cities you need very large sized pipes so, pre-stressed concrete pipe is also quite frequently used. Now, when we decide to lay down the pipe, we need to, sort of analysis hydraulics of the pipe network. So hydraulics analysis essentially means analysing the flow or velocity through the pipe and that depends essentially on what is the friction factor of the pipe? What kind of head losses that are expected to take? So there are theoretical approach to do that and their empirical formula to do that.

So theoretical approach likes see if one of the oldest one is basically developed by Chezy to this is known as the Chezy formula which is the velocity, average velocity in the pipe is the square root of rS where r is the hydraulic radius which is Area of the flow divided by weighted parameters. So, in case of circular pipe the area becomes Pi r Square and then the parameter of the pipe would be taken in and divided in order to get the hydraulic radius.

S is the slope of water surface of pipe essentially pipe is running full. So, it becomes the slope of Pipe and C is the dimension it is the constant which depends on the pipes material fiction. What is the pipe material friction. There was another formula which was proposed by the Weishbach and it was later on modified by the Darcy Weisbach not modified in fact more explained by Darcy which is commonly known as Darcy Weisbach equation which is where H is equal to 4 FLV square by 2g is the friction factor here.

We have discussed this formula earlier also while analysing head loss through pipe l is the length of pipe g is the dia and where is the average velocity of the flow?

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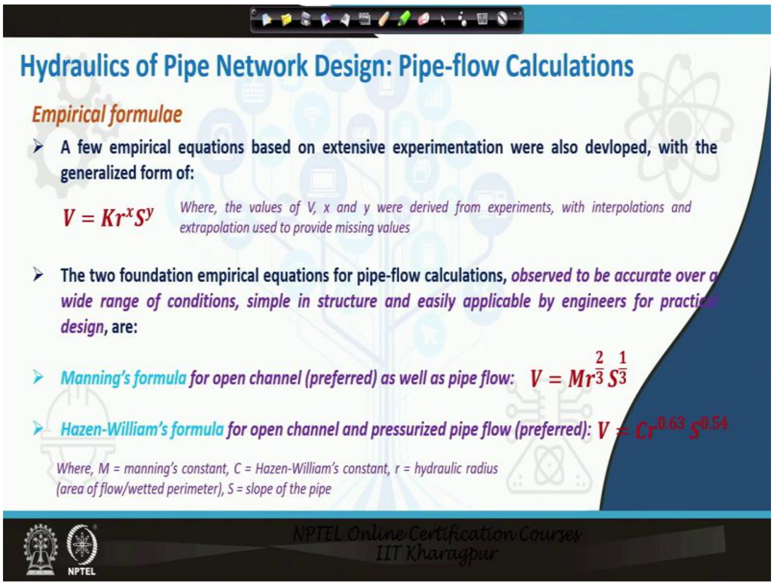

It is the total head or has lost that needs to be like seen through the pipe. The Empirical formulas show the generic empirical formula that were developed of nature is equal to K R to the power x and x to the power y again here, r is the radius and S is the slope and here v, x and y are basically derived from the experiment. And then winter portal interpolation and extrapolation we can basically estimate these values.

Based on this concepts, 2 more popular formula empirical formula which are used for Pipe Hydraulic Analysis or the Manning's formula where V is equal to Mr to the power 2 by 3 s to the power 1 by 3. M is the Manning's co-efficient here and r and s has the usual meaning, the hydraulic radius and the slope and the Hazen's William formula which is V equal to C r to the power of 0.16 s to the power 0.54. This is another popular formula for the analysis of the flow through pipes.

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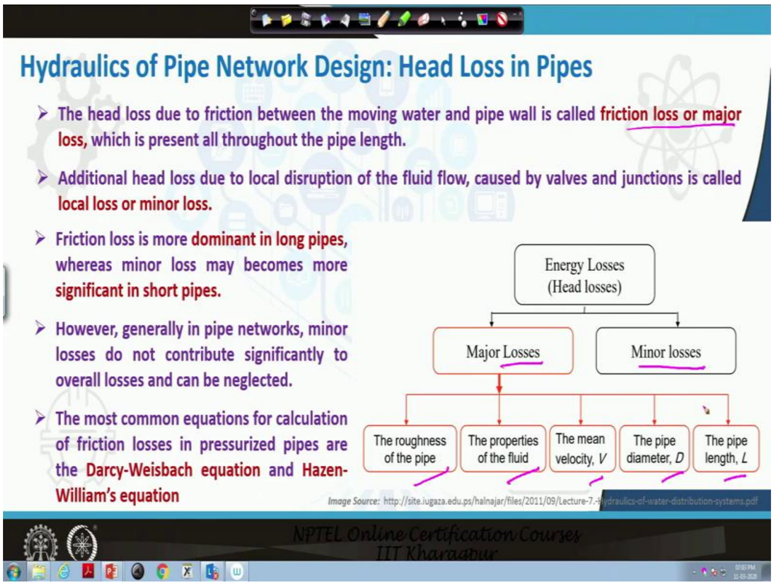

Then there are various types of head loss in pipe, which could be mostly divided into two broad categories. There are major losses and there is minor losses. Major losses essentially is because of the friction. So it is basically the friction loss which is known as the major loss, which is apparent flow of the pipe length. So when water flows to the pipes whatever section leads the loss in the head is known as major head losses. That depends on the roughness of the pipe, the properties of the flute, what is the velocity, what is the, what is the pipeline.

And and minor losses are the losses which causes because, because of the walls, junctions then entry of the water into a larger dia, say exit, expansion and contraction all those are known as all those are reason for local losses or minor losses. In generally, substantially if the pipe flows, friction loss which dominates and minor losses are the local losses are relatively of much lower magnitude and that is why they can actually be neglected.

The most common equation for calculation of these fictional losses is the Darcy Weisbach equation and Hazen's William equation.

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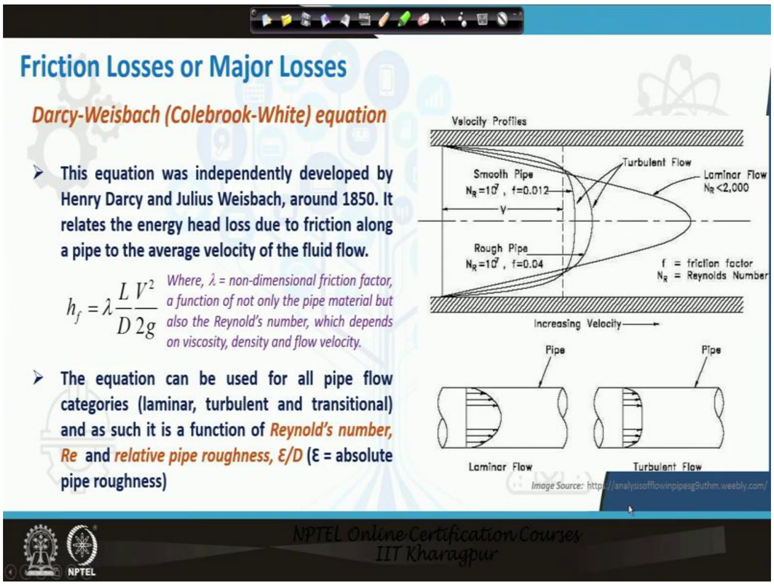

These are the two more common equations, which are used. Darcy Weisbach equation is basically HF is Lambda times L V square by 2 GD where this is a non dimensional friction factor, ok. Now this is typically function of pipe material, but also it depends on the Reynolds's number and Reynolds's number eventually depends on the viscosity density and the flow velocity. So it will depend whether there is too much turbulence velocity profile is going to be like this laminar.

So laminar flow is considered only up to range Reynolds number values less than 2000 Reynolds values greater than 2000 we get the turbulent flow. usually it will be transition generally for more than 4000 it will be considered as the turbulent flow. So this is the equation where basically the lambda depends again on the nature of the flow and then the laminar turbulent or transitional and it basically can be derived as a function of the Reynolds number and relative pipe roughness.

So where there is the absolute pipe roughness, so, we divide it with the dia to get the relative pipe roughness.

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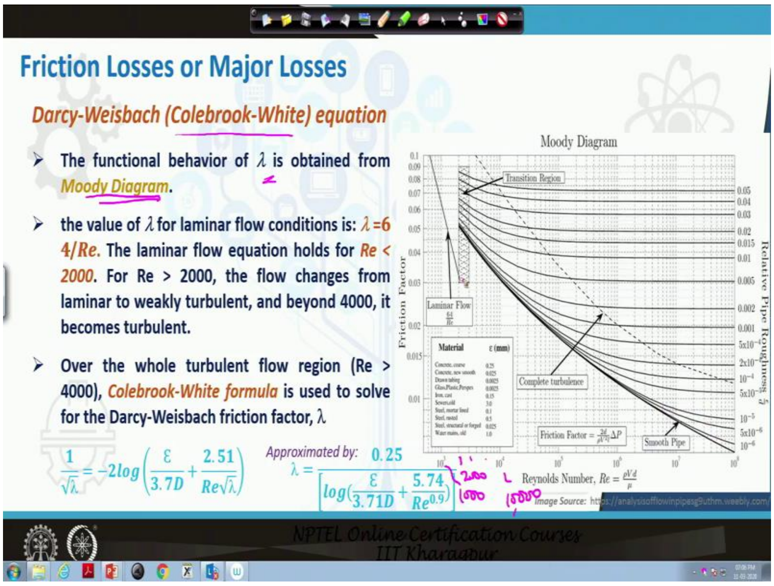

So, the Darcy Weisbach equation which is for turbulent region known as the Colebrook white equation as well, so the lambda values obtained from the Moody diagram typically and this is the moody diagram. So here we can see that this is the scale of Reynolds's number. Now, this is the 10 to the power 3 for pipe flow and this is your the then after thousand this value will be 2000. This is basically lock screen then 3000, 4000, 5000 that with this number is actually equal to 10000.

If you see that 2000 up till 2000 it is lamina, considered the laminar flow and the value of Lambda is basically 64 by R where R is the Reynolds number Rho vd by Mu from 2000 to 4000 it is generally the transition region which is considered and beyond that it is basically the complete turbulence region. So, the value of Lambda for laminar flow condition is 64 by Re ok this is actually 64 by Re and the laminar flow equation will hold true for Re value is less than 2000.

For greater than 2000 it becomes the transitional flow weekly, turbulent and beyond 4000 it becomes fully turbulent. And for turbulent flow we can use this formula in order to get the Lambda value which and the actually can be approximated by this. So, we can estimate the Lambda based on the Re and the values of a silent and the relative roughness what we call and then use this Lambda value for calculation of the loss, the head value of the apparently velocity through the system.

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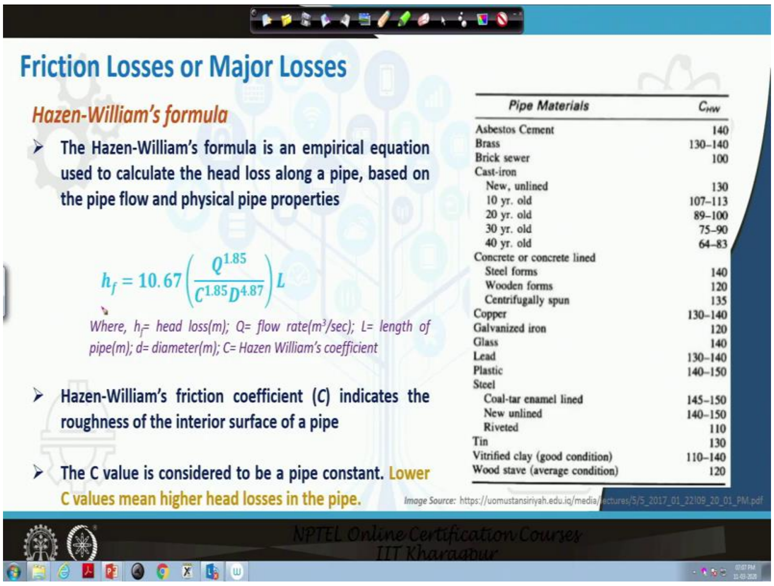

Then Hazen's William formula is another formula which is used. This is also kind of an empirical formula. So the head loss or frictional head loss through the pipe is 10.67. This is actually Size scale and then offers different scales like if you go to appear scales of the number changes, but in a size scale we are basically head losses in metre cube is in metre cube per second length, diameter in metre and see the hidden value Coefficient.

So, the head loss or major head loss or frictional loss can be estimated using this equation, where C is basically indicates the reference of the inner surface of the pipe. The value of C is considered to be a pipe constant, depends on pipe material to pipe material lower C values means higher head loss in the pipe. So if you see for different pipe materials, these are the kind of the Guided C values. So asbestos cement, brass, cast iron again for new pipes. The friction will be low and as the age of the pipe increases the friction values will overall frictional losses will increase because C value actually reduces.

So, C value lesser C value means higher head losses. You can see that as the pipe gets old the C value decreases, that means head losses increase in for new pipe, head loss the C value is higher so the head losses are lower. So this typical C values for different pipe materials, which is used in the Hazen William's formula.

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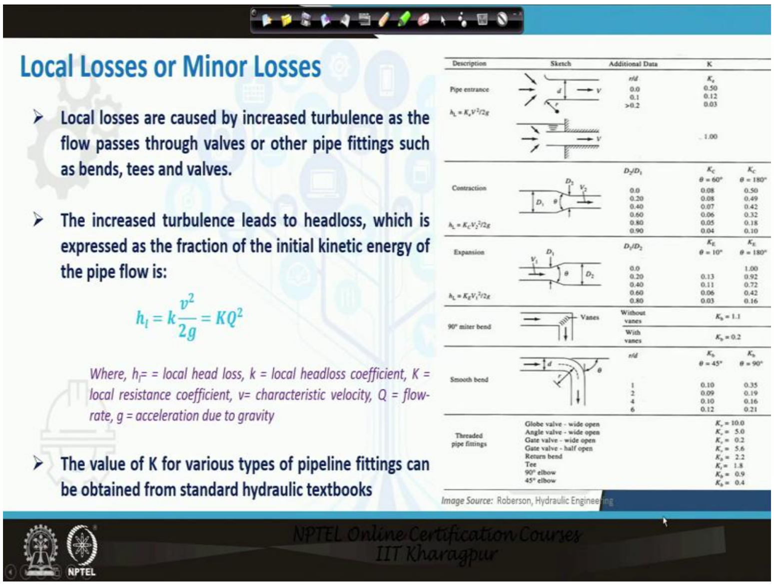

Then the local losses or a minor loss is basically losses that caused due to the increase turbulence because when water changes the transition phase, there will be increase in the turbulence which will be noticed. Either it is entering into a pipe from a system or basically it is exiting it is in a Reservoir and then exiting through a pipe. So its contraction, expansion, bend, smooth bend then the different kind of things can be there.

Whereas all these losses are typically approximated as Hl is equal to K V square by 2 GD which can be taken as a function of basically K into Q square typically, where Hl is the head loss or the local head losses. The value of k depends on the type of fitting and that can be thought of any standard hydraulic textbooks or any standard textbook would be having these values.

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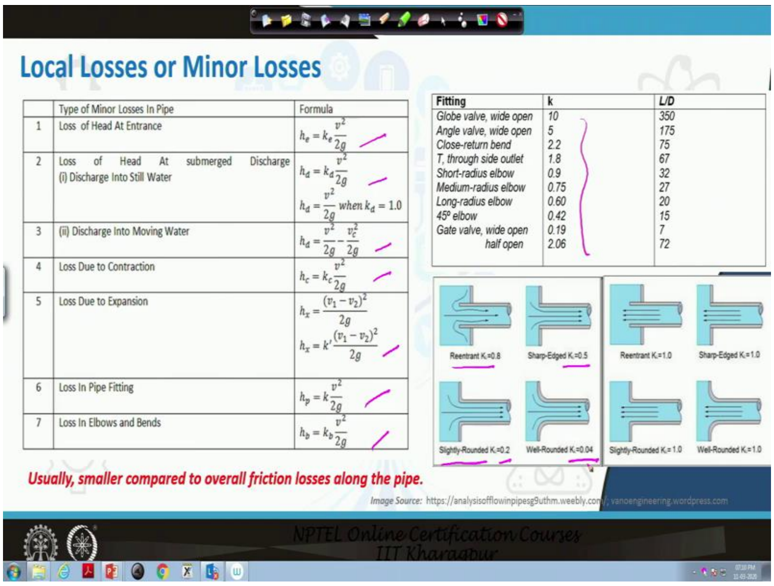

Usually, if you see the various minor losses in pipe loss for entrance loss for loss of head at the submerged discharge and discharge into moving water, loss due to contraction, loss due to expansion, loss due to pipe fitting, loss due to elbows and bends and for different fitting, these are the k values and based on the corresponding ld values. The k values also, varies so let us say given for a one specific type of minor losses say for loss of entrance so, if it is entering into the pipe, it is basically re-entrant, it is going to be 0.8 if it is a sharp edged.

It is going to be 0.5 k value if it is slightly rounded it is going to be 0.2 if it is very well rounded; it is going to be 0.04. So lesser the K value means lesser the head losses. So for a smoother system, obviously head loss is going to be less whereas for a sharp edged system it is likely to have higher head losses. So, this is for when basically re-entrant at the time of exit when from pipe it is going to a weaker section.

Then head losses k value is usually taken as one and that is independent of what kind of curvature it is providing whether it is in string to a smooth channel or it is string to a sharp channel the K value will typically be taken as 1.

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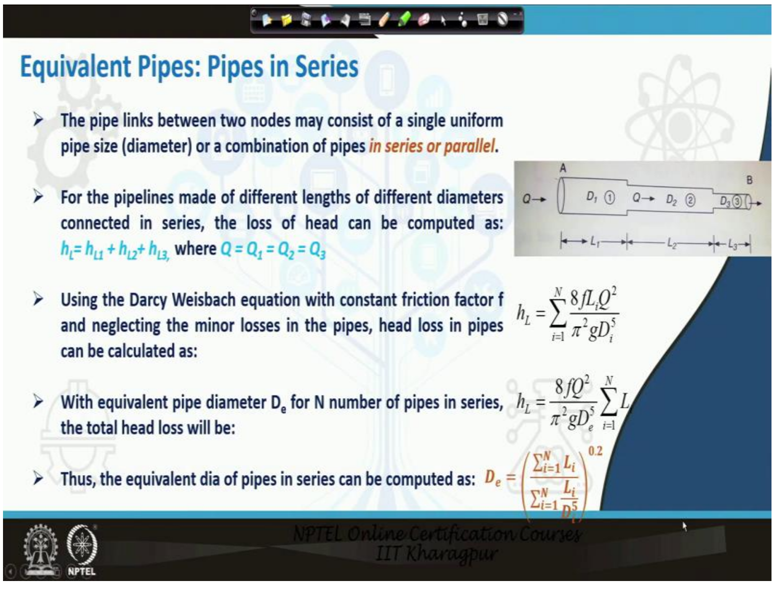

Then when there are several situations comes when we have more than one Pipe and we either connect them into series or in the or in parallel. So we can analyse these pipes as equivalent pipe. So for a pipeline that are made of different length or and of different diameters let us say we have one pipe line of length L1 dia C1 similarly L2 dia d2, L3 dia d3or more number of pipes and then we connect them in series.

So, in that case, the discharge because see if it is connected in the series. So, water flowing going in the first pipe, same flow is going into the second pipe, and same flow is going into the third pipe. So that means the flow remains the same. So the overall Q is not changing to each pipe it is the same. Q1 is equal Q2 is equal to Q3 and total head loss late let us say loss in this pipe is Hl1, head loss in this pipe is Hl2, head loss in this pipe is Hl3.

So, the total head loss that is going to happen is will be actually sum of these. So the total head loss is going to Hl1 + Hl2 + Hl3. If you know the minor losses neglect the minor losses and consider a constant friction factor, then the head loss in pipes can be calculated as this using Darcy Weisbach equation. Since instead of velocity, we have taken discharge. So, that equation can be given in this form as well.

So basically for this dia pipe of this length it will be and then we need to sum for a pipe of all length. The discharge is same from all friction factors is going to be same from all. So, we sum and we get the total head loss. Let us say, if we have an equivalent pipe, instead of these Combination of various pipe then the head loss to the equal to it is the dia of the equivalent pipe. Of course length is going to remain the same H11 + Hl2 + Hl3 total length is L.

So if we take like summation from I is equal to 1/2 l of the eye, that means total length this become the total length of the pipe essentially and if d is the equivalent dia of the pipe, total head loss in one single equivalent pipe can be estimated using this way. And this is the total head loss. So if we equate these 2, now if a equate with these two, so we can basically compute the equivalent dia of the pipe.

From the rest will get cancel an equivalent dia 3 will be actually the summation of the length of these different time is the total length divided by length dia to the power 5 for each Pipe and square root of that will give us the dia. That is what is kind of equivalent dia in the pipes when they are connected in series.

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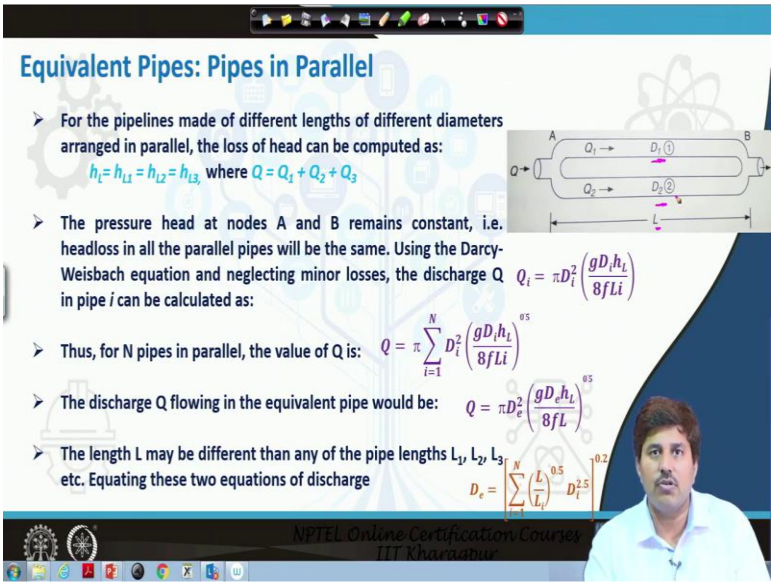

What happens when the pipes are connected in the kind of parallel to each other? So let us say you have 1pipe here, of dia t1, another pipe of diameter t2 pipes if these pipes are connected in parallel, generally, length is equal but it is not mandatory case actually be of different length as well. But in any case if pipes are connected in parallel, they are connected so head loss between these two points are going to same.

So that means head loss to the first pipe will essentially equal to the head loss to the second pipe as well. So the head losses here are going to be the same and discharges are going to be added because if discharge the total discharges Q this one is carrying q1. This one is carrying Q2, say you have another pipe which is carrying Q3 ok, so then Q is going to be equal to Q1 + Q2 + Q3 upto basically q and whatever is the number of pipes is there.

Again, using the Hazen William's equation and neglecting the minor losses, the discharge in pipe i can be given using this expression. And for n pipes in parallel, if you want to get the total discharge so will have to add this from i is equal to 1 to n and then we add all these discharges. This discharge can be given from an equivalent pipe of length L, so if the length is equal and pipe length L and d is the dia, total discharge can be estimated this and equating again, equating these two, we will get the equivalent dia of the pipe basically there are pipes of if even if their pipes of various length L1 L2 L3, so, we will have that.

When the pipe lengths of each pipe same, then essentially, this will get cancelled and will be basically getting d to the power 2.5 square root of that. So that is going to be our equivalent dia in that case. This is how we basically analyse the pipes, in parallel pipes, when we add more than one pipe in the series. And this particular class here only in the next class will be discussing about the analysis network analysis for as we discussed different type of networks in today's class. So I will take up some method for network analysis in the next class. So, thank you for joining. See you in the next class.