Hydraulics

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Module No. # 08

Pipe Flow

Lecture No. # 03

Pipe in Series and Parallel

We are using a term that is f, that is, friction factor, well. And that friction factor is very very important, because the entire value of head loss that will depend on, because other things are known, l is known, then d is known, velocity square or velocity we can calculate once we know the q, the discharge and the diameter of the pipe because discharge by area, that will give us the velocity. So, that way this is one issue, that, but this f is very important, if we can calculate that, then we can calculate the other part of course, though I am saying, that velocity can be computed by q by say pi by 4 d square, d is the diameter, but this diameter if we fix beforehand, then this way we can calculate the velocity. But how much fiction loss will be there, that is very very important to know, how far our water will be going or to what head we can take the water up if our existing head is something in our hand, well.

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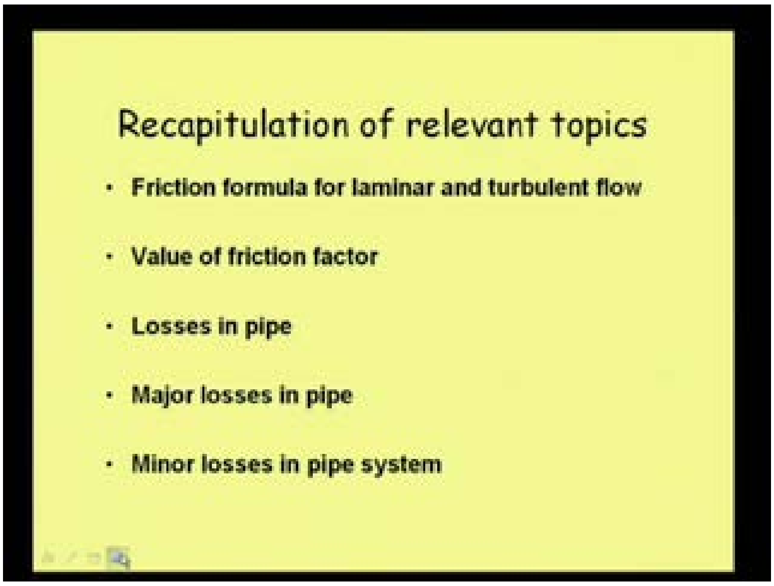

So, that way, the value of friction is also very very important, this particular friction factor and we, we discussed in the last class, that friction factor for laminar flow is say, inversely proportional to Reynolds' number, but it is linearly varying with the Reynolds' number. So, but when the, it, it moves to the turbulent zone in laminar it is like that, but when we moved in to turbulent zone, that is, when the flow becomes turbulent, then the roughness of the pipe, that is, the roughness of the pipe inside of the pipe, that is, when roughness of the pipe become significant only when the flow becomes turbulent, well.

So, say, we, if we write the roughness as epsilon, then epsilon divided by the diameter D, that way we did derive 1 parameter or we stated about 1 parameter, dimensionless parameter, that is the roughness, how much rough in it is related to the diameter D. If the diameter is very large, then of course, the roughness of smaller roughness may be insignificant, but if diameter is small, the smaller roughness itself can be significant. So, that way it is always proportional or it has link with the diameter, the, we cannot say roughness very explicitly this value.

Well, anyway, this roughness by diameter depth parameter we did consider and this roughness by diameter, that value if increases, then the value of friction factor increases, but in turbulent flow only. In laminar flow this roughness has nothing to do much with the say, friction factor. The reason is that in laminar flow, the flow moves as layer and on the boundary they remain an almost static layer, which is not moving, which has the velocity 0 and it is covering the roughness. So, the other flow are moving, say over that particular layer, which is attached to the boundary and that is why this roughness is not becoming that much significant. And then, knowing this f value and then using the Darcy's Weisbach formula, we can calculate this head loss. This head loss, what we are talking about is the energy loss due to, say, friction or length of the pipe, it is quite significant, but there are some minor losses in the entire pipe system. Entire pipe system means, there may be joint, there may be some connection, there may be some fittings in the pipe, there may be bend, when the pipe is moving from one point to another point, to change the direction we can have bend, we can have, suppose some, somewhere it may be required to reduce the length, suppose original length is something, then we are reducing the length at certain point to some smaller value, original diameter.

So, original diameter is supposed larger and then from that larger diameter we are reducing it to a smaller diameter. Well, in that case, there is a contraction and similarly, from a smaller diameter suppose we are increasing to a larger diameter, then there is an expansion. So, when there is a contraction or expansion, then also there is loss of energy and those losses of energy occur because of variation of velocity due to such existence of such, say junction or say reducer or say expansion. So, and those losses we term as minor losses; these losses are termed as minor losses.

So, in loss of pipe we can have, say there is major losses or there can be minor losses in the pipe system, but minor losses are not that significant if the length of the pipe is quite large. If it is a sufficiently long pipe and if there are 1, 2, that sort of small minor losses, then it is not that much significant, even minor losses occur at the entry point in the pipe. Suppose, pipe is getting water from a tank, then at that entry point also some loss occurs. Well, say, that loss we did mark as 0.5 v square by twice g and at the exit point also, there will be some loss. So, this loss at, at the exit point, loss is generally taken as v square by twice g; it is taken as v square by twice g. So, those losses, generally we can neglect if the pipe length is too large, but for a smaller pipe length will have to consider those things, because if the pipe is long, friction loss will be much more.

That is, the loss calculated by f L v square by twice g will be quite large and then, this minor loss can be neglected for a smaller length of pipe. This f L v square by twice g, D will be having smaller value and in that case, this entry loss, exit loss or loss in fitting will, will be of the order, that it cannot be neglected as compared to the friction loss; in that case, those losses are more important.

Well, with this we will be moving into our today’s class, that say, pipe in many a time we need to join in series, several pipes, one bigger diameter pipe, one smaller diameter pipe we need to join in series; sometimes equal diameter pipes are moving parallelly, source is same, from the same source the pipes are coming and then, pipe, one pipe is coming and then from there, suppose we are dividing the pipe into 2, 3 different parts and then it is moving parallel to each other or parallel means not physically parallel, but these are moving on principal, parallelly to each other and then again joining at some point, say downstream and, or say at a, at a point after sometime. And then, how to compute the friction loss or the head loss in these sort of pipe system, those we will be discussing in this particular class, just 1 minute. (( ))

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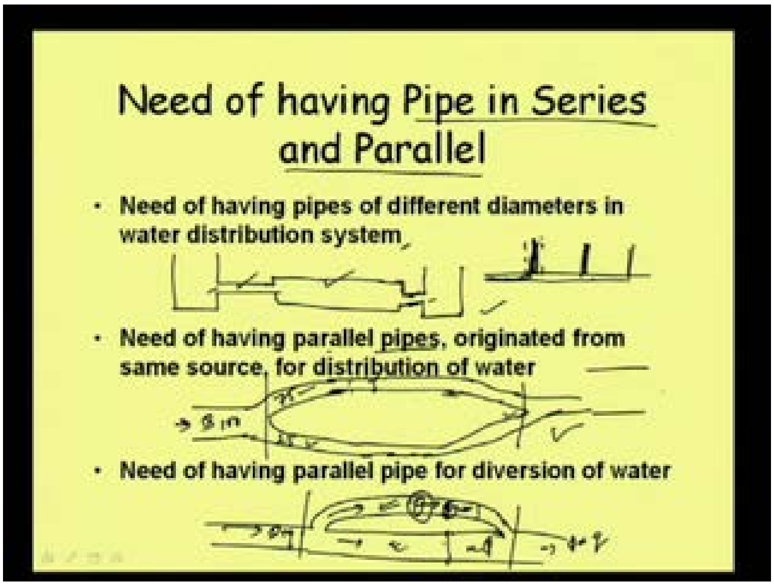

Well, first let us discuss, what are the needs of having, say, pipe in series, pipe in series and pipe in parallel, well. So, need of having pipes of different diameters in water distribution system. Well, say, we are having in water distribution system, we can always have that 1 bigger diameter pipe is coming say for example, and at a downstream point we want to reduce the discharge from a particular point. In that case, we will be contracting the pipe from that point, so that discharge automatically gets reduced in that particular pipeline and so this is one need, that we, we need to change the diameter of the pipe from one point to another point.

Even in household system also, when the main pipe is carrying from the tank it is moving. Suppose, this is the main pipe, it is coming from the tank and then, from that pipe we need to join smaller pipe in, in, in this system, say if we make it bigger, then entire water will be moving; suppose this is also bigger, then entire will be, water will be moving in this direction, no water will be moving here. So, to avoid those things, we sometimes reduce this pipe and then, we take, suppose some amount of water is moving there, then it is the rest amount is going here and then it is moving here, so like that. And then, if we want to calculate the loss from here to here, then also there is a question of change in diameter, this is one issue.

Then, suppose in a system we want to, we are having, say from tank water is coming and this size of pipe only we can join at this point due to some constraint. Well, then it will be carrying waters to say, another tank and then, here also we can join this size of pipe, well. Because the pipe, this tank may already be having some fittings or there may be some other constraints that we want to have this. But if we carry the water by this length of pipe, then it may happen, that huge amount of head loss occurs because if we increase the pipe diameter, then head loss will be reducing. Now, say for that purpose, what we can do? We can increase, increase the main section like that and then, we are having a situation that pipe of different diameters are joining and then we need to know, how much will be the head loss from here to here.

In that case, we are getting a pipe, which is in series. This pipe we can say, that it is a combination of 3 pipes - 1, 2, 3. We can say it is a combination of 3 pipes in series, one after another, and the reverse situation may also happen. Say, from the source we can draw water with a bigger pipe due to some constraint, then that bigger pipe is coming. But suppose, this pipe needs to be carried through a city and so different heavy area, already busy area. Then, there, suppose it may not be possible to carry that big size pipe, then we may have to reduce the pipe and then we are carrying it downstream. So, that way, for different practical needs, we may have to have pipe of different diameters that we join in series.

Similarly, there is a need of having parallel pipes. Say, from a source it is originating like this and then we want to carry a discharge, this discharge, but this discharge we may be interested to distribute to some people residing here, some people residing here. So, what we will do, we can divide it into 2 parts, we can divide it in 2 parts like this, and then some amount of water is going in this side some amount of water is going in this side. Again, say, after, after being getting all this water here, then we want to again join this in, in the same pipe. So, then, what is the situation, that this pipe and this pipe, these 2 pipes we can say, that this pipe are parallel. Of course, as I was saying, that it should not be physically parallel line like this, it is not physically parallel line, this, it is not like this, means, principally, say these are starting from this point and going here and there, joining here like that parallel circuit of electricity, or say series circuit of electricity, that we get.

So, that sort of concept we apply here and in this situation we need to know, that several requirements can be there, that is, we may be interested to know, that what should be the diameter of this pipe if we are interested to carry, suppose 100 cusec is coming. Then, say, well, we may be interested to know, that here, suppose more population is there, then we want to carry 75 here, 25 here. Now, how we need to proportion this diameter, so that this amount of discharge we can get?

Similarly, need of having parallel pipe for diversion of water sometimes, we, it becomes required to divert the water from one main pipe to another pipe and to, to another direction. And in that case, suppose this is, main pipe is coming and we want to divert this water like this, well, may be for some reason, may be for some reason, that we may be interested to do so.

Say, there is, there are some faults in this pipe and water cannot be carried through this part, say in that case, of course, we may have to discard this thing by a valve and then we may have to carry these things. That is, of course, but this system we are keeping, suppose thinking, that there may be some problem in this part and we are keeping a valve of course, here. And we want to keep a system like that, say, it, it may be there, may be some joint in this pipe and it is suppose passing through some polluted area. If the polluted area enters into, polluted water enters into this water system, then it will be polluting all these things. And knowing all these things, suppose as a precaution we are keeping a parallel pipe to this one in this part, if, because suppose, generally we may not be interested to have this one because head loss, if we move for a longer distance, will be more, but as a precaution we are keeping these things.

Now, once we find, that this sort of things happening, then we may have a provision, that we are closing this valve and we are closing that valve, and then we are carrying the water through this one, but if it is not happening, then say, water is moving by this pipe as well as by this pipe, and in that sort of situation also, we are having a parallel pipe system. And there is another need, sometimes say, we want to know, how much discharge is flowing through this pipe and this pipe is suppose of very large dimension, this pipe is suppose very large dimension and it is very difficult to measure the discharge in this pipe. That means, for discharge measurement we have some devices and those devices, the diameter, that the, those devices, say, we need to fit into the system, so that we can measure the flow and those devices' diameter may not be depth large. In that case, we can have, we, we may be requiring to have one smaller diameter pipes through which, suppose, discharge flowing we can measure.

So, in that case, say, if we have a smaller, suppose this is a smaller diameter pipe and we are measuring the discharge here by fitting our discharge measuring device here. And then, knowing this discharge and if we know, if we know the hydraulics of this entire flow system in the pipe, then just measuring this discharge and knowing the diameter of this one and that one, it will be possible to find out how much is the total discharge flowing in this pipe because this discharge also we can calculate in terms of this smaller discharge. Once we calculate this one, we can calculate this discharge, say q, then it will be q plus q; total discharge will be q plus q.

So, for various purpose in our day to day life, in while, would working with the water distribution system, we may require pipe in series and pipe in parallel, knowledge of these things are required, and that is why, let us move to this particular topic, that head loss in pipe in series.

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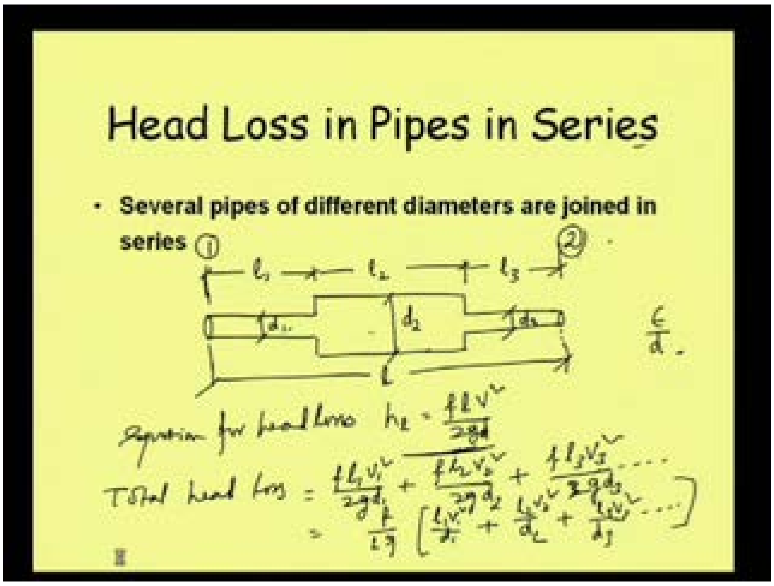

So, if the pipe system or several pipes we are joining in series, then we need to know, how much will be the head loss? So, let us discuss first that issue. Well, suppose, several pipes of different diameters are joined in series. Let us state, say, this is one pipe and then, from here, some of the pipe diameter is increasing and we have a diameter of this size and then, again it is decreasing and we have a diameter of this size. Well, let the diameter this be, say d 1 and diameter of this bigger section is d 2 and this smaller section may be d 3; not necessary, that d 1 should be equal to d 3, you just consider, like that several pipes of different diameters we are joining in series well And then length of this pipe, length of this pipe is say, from here to here it is l 1, length from here to here l 2 and then a rest part is l 3, so these we are joining. And of course, say from here to here, our total length from here to here, the total length is say l, total length we can write as l.

Well, now, how to analyze this pipe system? Now, we will be using the equation for head loss, say, head loss, we know equation for head loss, h l is equal to f l v square by twice g d, d stands for diameter, in the previous class perhaps we were using capital D, but here d stands for diameter. Now, well, this equation is valid, this equation is valid for all the pipe. Now, if head loss, total head loss we want to know from section 1, say this is our section 1 and this is our section 2, because this is a pipe in series and we are joining it into, I mean, water is moving from here to here and that sort of system will, will be joined to say, may be, in a total bigger water distribution network, we are having a segment of this system and then it is joining. So, we, we are interested now to find out how much will be the head loss between 1 and 2? Further, here, there may be it is connected to some other section or another network from where the flow is continuing. So, we are not talking about all those issues, our interest is to find out what is the head loss between 1 and 2.

And obviously, as these pipes are in series, so head loss will be summation of head loss of each of the pipe. So, that way, we can write the total head loss is equal to say, total head loss is equal to say f l 1 v 1 square by twice g plus f l 2 v 2 square by twice g plus f l 3 v 3 square by twice g, and if there are more sections, then it will be coming more in number, I mean for all pipes.

Now, here, when we are writing, say f, this f for smaller and bigger diameter pipe we are considering to be same, we are considering to be same, but of course, it may not be. If the diameters are changing too much, then this f value may not remain same. The reason is that when suppose, the same material we are using, the pipe material, suppose GI pipe and we are using and or may be PVC pipe we are using, material is same, but the diameters are different. If the material is same, then the internal roughness of that material will be same, means our epsilon value will be same, which represents basically the roughness. Well, but the diameter is changing.

So, when diameter is changing, then epsilon by d parameter, that this value is different from this pipe and that pipe and if it is significantly different, then as we know from our diagram, that we discussed in our last class, that this epsilon by d value influence the friction factor; higher the epsilon by d value friction, factor will be higher. So, that way, this f value may not remain same in all the pipes. If our, I mean, pipe diameter change in pipe, diameter is quite large. Well, but here of course, if we consider this to be same, then we can further simplify this expression, we can further simplify this expression to have that, this is equal to say, f by twice g. Then, we can write, say or d we are not writing, f l v 1 square by twice g d 1, d 1 we just forgot to write here, d 2, this is d 3. So, it will be say, l 1 v 1 square by d 1 plus l 2 v 2 square by d 2 plus l 3 v 3 square by d 3. Well, so this is the relation.

Now, again, the next step, that the velocity v 1 or v 2 or v 3 will be different in these pipes, well. And which may not be known to us, which will not be rather known to us if we do not measure these things, but we need to express this in terms of a parameter, which we know and that is what the discharge, because velocity is nothing but discharge divided by the area. Well, discharge divided by the sectional area. Now, the sectional area, sectional area we know because the diameter is known to us. So, velocity we can have in the form of that q, which is discharge q divided by pi d square by 4; pi d square by 4 is nothing, but the discharge.

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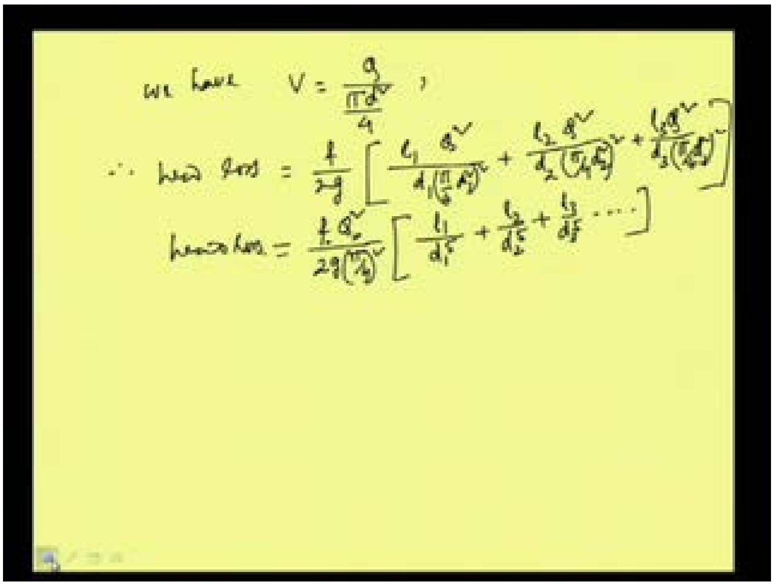

So, we can write it in this form, that we have, we have, say v is equal to Q by pi d square by 4. Therefore, this equation, what we can write, that is head loss, head loss is equal to say, f by twice g already we had, then we can write it, we can replace it, this by l 1 by d 1 was there, then in place of v 1 square, we can write Q square by pi square 4 square, we will write it together, pi by 4 d square whole square, this we can write. And now, this is d 1 plus l 2 Q square by say d 2, then again pi by 4 d 2 square and it is whole square, because we are talking about v square. So, v square is equal to Q square by this entire to the power square plus, say l 3 q square, then d 3, then we can write pi by 4 d 3 square whole square. Well, so now, here we have some more common terms and that we can bring out, that is, Q square by pi bar pi by 4 whole square and d can be written as d to the power 5. So, what we can do? Say, f Q square by twice g and then, we have pi by 4, so this square. So, this entire things we can bring out and here we can write, say l 1 by d 1 to the power 5 plus l 2 by d 2 to the power 5 plus l 3 by d 3 to the power 5 and that will continue, if we have several pipes, if we have several pipes we can continue with this relation.

And then, now our total head loss we can calculate by this process, total head loss we can calculate this process. In a pipe we will be knowing, that how much discharge we are carrying, that is known to us. Then, f of course, we are considering f is same value, constant for this 3 pipes and then these are all constant, then l 1, the length of each of the segment will be known to us, diameter of each of the segment will be known to us. So, that way, we can calculate the friction loss.

Now, the next point is that for various practical reasons, as I was saying, that this pipe segment may be a pipe segment, which is connected to a bigger pipe network system and for analyzing the entire flow process, say in the bigger network, many a time it becomes required for us to know head loss between these 2 pipes.

And the 2nd point is that we need to know, what can be the equivalent diameter for this sort of pipe? Well, what can be the equivalent diameter for this sort of pipe? Say, for some reason, initially we have joined these things with pipes in series, several pipes in series, then we have found, that we, now we can have a single pipe from say this point, inlet point to outlet, outlet point. So, from here to here, earlier due to some reason we were joining this sort of things and then, somehow, now we are having in a, in a position, that well, we can join it, it by a single pipe. But while joining these things, we want to ensure, that other things are not changing, means, because if it is connecting, suppose it is connected to a bigger network, if we change this pipe, then the head loss in these things, if it changes, then it will influence the flow in the other pipes and we want, that other pipe should not be disturbed or any change should not come to the entire system. So, we may be interested to know, that what will be the equivalent pipe diameter if we want to change this pipe by a single pipeline.

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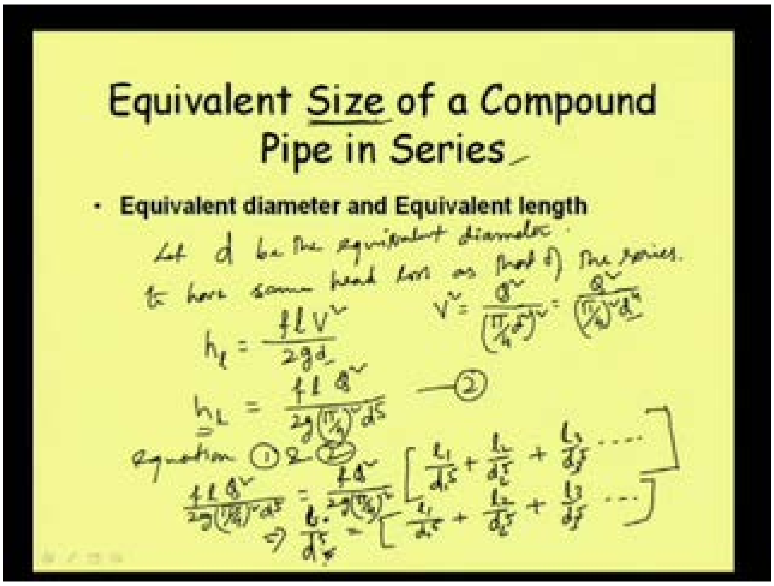

Well, so, for that we talk about equivalent pipe diameter in a system of this kind; in a system of this kind. So, we will be talking about equivalent size of a compound pipe in series. Here, we are intentionally, rising, writing this as size, not as diameter. Although we normally talk about equivalent diameter, why, because sometimes it may happen, that yes, to replace this series of pipe, we have a pipe of this much diameter, that means, diameter is given as fix. Well, we have this much diameter of pipe, now you replace this pipe system, that is, the, which is in series by this single pipe. In that case, but your, your constraint is that you need to maintain it or you need do it in such a way, that a length, that the head loss in the system remains same, so that the entire network, the bigger network to which it, this is just a component, may not be disturbed.

Well, in that case, if it is to be done, diameter is already given, so you cannot calculate the equivalent diameter and in that case, you can have equivalent length. If diameter is given you can have a, suppose if your diameter is large, larger than, if your diameter is smaller, then what is the required diameter. Then, to have the same head loss, you can change the length of the pipe. Of course, shortening the length will be difficult, say if it is a very bigger diameter pipe, you want to short it to have the same head loss that may not be possible. But lengthening of the length, suppose the existing length is something, then you can have a curve and you can have your a longer pipe. So, that way also it is possible. So, we are talking about equivalent size of compound pipe in series.

Well, how we can get that? Say, let say d be the equivalent length, it is very simple, d be the equivalent diameter; d be the equivalent diameter. If d is the equivalent diameter, then what we can have? To have same head loss, to have same head, head loss at there as that of the series, to have same head loss as that of the series, as that of the series, well we know, that h l, head loss should be equal to, say f l this time. And this l is the total length of the pipe, this l is the total length of the pipe, just I can show you here, this l is this length and for this length we will be having an equivalent diameter, may be, say we want to get a pipe of this type, we want to get a pipe of this type and we want to get a diameter d and length l. And that we are talking as, say equivalent diameter, equivalent pipe, equivalent pipe and of course, as it is smaller and this is bigger, so ultimately this equivalent diameter will be definitely somewhere intermediate between this d 2, d 1, d 3, something like that.

Well, just we are drawing it. So, well, so, this length is supposing that one, f l, I mean length of the series total. So, l and this is v square, f l v square by twice g d. Well, here also, this v square can be replaced by, v square is nothing but this is equal to Q square by pi by 4 square and d square, d square whole square. So, what we can write? This we can write pi by 4 d square whole square, this is equal to say, Q square by pi by 4 square and d to the power 4, we can replace this one and then, just replacing this part, what we can have, that is, this becomes f l, then it is Q square twice g is there, then pi by 4 whole square is there and this d and this d to the power 4. So, it is d to the power 5, well.

Then, we had one relation already, that head loss h l is equal to this one. If we put this as equation 1 and then this equation as equation 2, so because this is the equivalent, this head loss is equivalent to this particular head loss, so what we can write? Equating 1 and 2, equating 1 and 2, because this head loss is same, so what we can have, that is, f l Q square by twice g pi by 4 square, then d to the power 5 is equal to, now we can write this part, that part will remain same, but inside will be changing, that part is f Q square by twice g pi by 4 square, that part will be same. Then, we will be having l 1 by d 1 to the power 5 plus l 2 by d 2 to the power 5 plus l 3 by d 3 to the power 5 and of course, if there are more in series, then it will continue.

Now, we can see, that this part and that part is same, I mean, this Q, Q f, f and of course, the friction factor, again for the equivalent diameter also we are considering as the same value of friction factor. And of course, we should remember if the diameters are changing grossly, then we should consider different friction factor like, but right now considering this as f, what we can have, that this part will be same. So, here it will be l by d to the power 5 is equal to, d is the diameter, l by d to the power 5 is equal to say, l 1 by d 1 to the power 5 plus l 2 by d 2 to the power 5 plus l 3 by d 3 to the power 5 and they are good and this is very important relation, this is d to the power 5; of course, d to the power 5.

And this relation is important, why? Say, we want to, for finding these equivalent diameter, if these things are known, say l 1 is known, d 1, l 2, d 2, all are known and we know the total length, we know the total length because if the pipe is joint in series, pipes are joint in series, then the total length will be known. In fact, for the simple case, if we sum up this length of individual pipe, it will give us the total length, of course. Then, if we want to increase the length or decrease the length that is the different issue, but otherwise, if we join, if we just sum up the length of each of the individual pipe, then that becomes the length of the equivalent pipe, so this l is also known. Then, our interest is to find out d. So, from here, if we solve, we can find out what the value of this d should be, so that our head loss does not change grossly.

Well, well, with this discussion on say, determination of equivalent diameter and of course, as explained earlier, if the diameter is already given to us, say we are asked to change the entire pipe system by a pipe of given diameter. In that case, to maintain the other part, we need to change the length, well. So, either length or diameter we can calculate once one is known to us and that is the very concept of equivalent size of a compound pipe in series.

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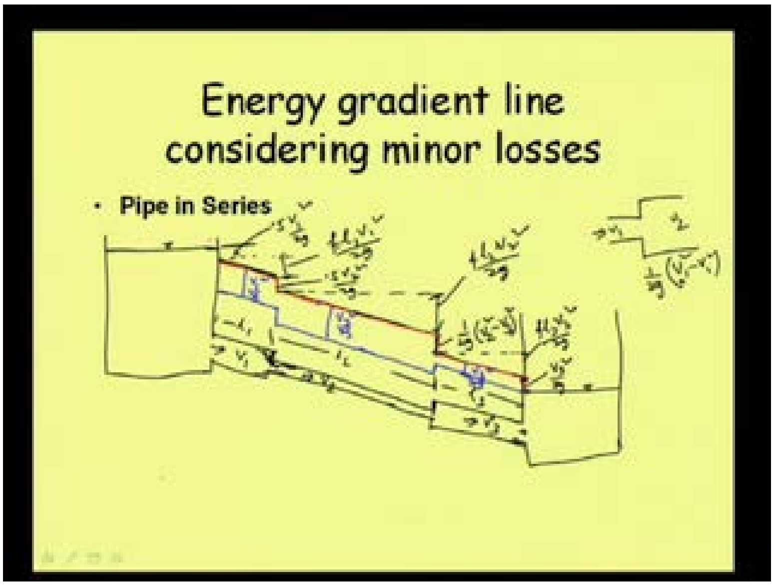

Now, what will be the energy gradient line if the pipe is carrying water from one tank to another tank through a series of pipe? Well, say, this is one tank, this is a tank where we have water and from here, say, we are planning to carry the water to a tank at lower elevation, somewhere here. Well, here level is this one and when we are carrying the water from here to here, say initially, we are having a larger pipe, suppose and then somehow, we are continuing with a reduced length, and then we are moving this way and then from here again, we are having a larger pipe length, this is that reverse of what we did draw, but any situation we can have, so this is the condition.

Now, say, how we can draw the hydraulic gradient line in this particular system considering the minor losses. So, here, lot of minor losses will also be there. In the last case, when we were calculating, say, head loss, then we did not consider the minor losses, but here the minor losses will be coming because we are talking about carrying the pipe water from one tank to another tank, and this length may not be very large. But the, we are putting a reducer to reduce the length of the pipe and then we are putting here the reducer from the opposite side to increase the pipe from say, this diameter to that diameter. So, and this, they are in, in these point we have some loss. At the same time, at exit also we have some loss; at entry point also we have some loss, minor loss. So, those losses will be playing a role in this part. Let us see, how we can draw this sort of energy gradient diagram.

Well, say our total head may be, say, total, we are starting from here, this is at the point, it is static. So, it does not have any velocity, so this is the total energy, we can say, say z plus these things, if we add here, it is, so this is the total head and from here we are starting. So, initially, at entry point, initially at entry point, there will be some loss and that loss is, as we know, that loss at entry is equal to 0.5 v square by twice g. And of course, which velocity, that velocity here is say v 1, velocity here is v 2 and velocity here is v 3. So, at the entry point, the loss is say this much, this is equal to 0.5, v 1 square by twice g, that loss is just straightaway it is dropping here and then we are having the drop q 2, friction loss.

So, up to this point, again say, up to this point there will be friction loss and so starting from these, the energy gradient line it will be moving downward because there is a constant velocity and because of that constant velocity, there is a head loss, friction loss. And then, this friction loss, we are getting up to this much, then this value from this point to that point, this loss is nothing but we can write f l length, we can give this length is say l 1, this length is l 2, and this length is l 3, well, so f l 1 v 1 square by twice g; f l 1 v 1 square by twice g. Well, then we have at this entry point, it is the loss due to contraction, loss due to contraction, and in the previous class we did discuss about the loss due to contraction. And this loss is basically, just to recall, that water will be moving this way, then it will be expanding from the vena contracta and the loss is because of the expansion from this point only, not because of this contraction basically. So, this loss is dependent on the velocity of this particular pipe. It is, we, we could express these as, say in terms of this velocity v 2, because it is basically the loss, that is occurring because of this contraction.

The flow is moving like this, there is a vena contracta, then from here it is expanding and say, loss is because of this particular point. So, and this loss, although we could, we were talking about some coefficient of contraction, c c, we were talking about and then based on that c c ratio, we can find out this value exactly. But in general, after simplifying again, though some tabular value is there based on the ratio a 1 and a 2, what can be the value of c c? a 1 a 2 means area ratio of the bigger diameter pipe and the smaller diameter pipe or say, sorry, it was a smaller diameter pipe to the bigger diameter pipe, that ratio. So, based on that ratio, we can find some c c value and then, that c c value, using we can find, we could find one expression by which we can find the minor loss.

But if we consider this in an approximate term, this can also be expressed as 0.5 v square by twice g; that also we did mention in the last class.

So, here, again there will be a drop of say, 0.5 v 2 square by twice g and from here, there will be again friction loss like this, there will be friction loss like this up to this point, up to this point and there will be then expansion. Now, this expansion, well, then up to this point there, there, there this loss is there, then from here to here, what loss we are getting? From here to here this loss is nothing but the f l 2 v 2 square by twice g, then here we have the loss due to expansion and if we recall the loss due to expansion was, say v 2 square, v 3, I mean this downstream velocity square minus upstream velocity square, and then we could get the expression as, sorry, it was, say, just let me write it, draw it here. If it is expansion of this sort, if it is expansion of this sort, this is our v 1, then this is v 2 velocity here and our equation was, say 1 by twice g, it is v 1 square minus v 2 square, v 1 square minus v 2 square because v 1 will be larger always in the smaller pipe.

So, here also the loss will be there, will be a sudden loss, again due to this particular drop and this drop is equal to say, 1 by twice g and here v 1, that is the upstream velocity, here is of course, v 2. So, it is v 2 and downstream velocity is v 3. So, v 2 square minus v 3 square, so that way we are getting. And then, from here again we have a, I mean, fall here; again we will be having a fall (( )), then this loss from here to here will be of course, here, though I did draw the line here, the water tank level, but this will not be the line, this will not be the line, line will be somewhere else. And well, so this loss is, in fact, again this from here to here, this loss is f l 3 v 3 square by twice g and then from here as there is an exit point, so there is a head loss at this point. So, that exit loss is suppose this much, that exit loss is this much and that loss is equal to v 3 square by twice g. Basically, this loss is v square by twice g loss, that exit is equal to v square by twice g. So, this loss will be v 3 square by twice g.

And ultimately, at this point, the water level in this part will stand because the total energy difference is from here to here, is this much. Well, earlier, I was drawing it here may be, if we do not consider all those things it will be coming some in the top, but of course, that was just I was drawing arbitrarily. Now, when I am drawing the head loss, then coming here we are finding that water can be standing here also. Then, if we draw the hydraulic gradient line, this is the energy line, this is the energy gradient line and well, let me just put a different color, so that this can be very clearly seen. Say, this is our hydraulic gradient line, this is the hydraulic gradient line, then if I draw the energy line, sorry, sorry, sorry, this is the energy line, this is the energy gradient line and if I total energy line, basically then if I draw the hydraulic gradient line, then as we know, that from the total energy if we deduct v square by twice g, which is velocity head, then we will be getting the piezometric head or that line itself represents hydraulic grade line.

So, from each line or for from each of this point, if we just drop a distance of say, v square by twice g, this will be v 1 square, say v 1 square by twice g, then we are getting a line parallel to this one, which is our this, I mean, which is the say, hydraulic, hydraulic grade line and then, from here this drop will be more because this is smaller pipe and then, so velocity will be higher. So, it is, say v 2 square by twice g and so it will be dropping like this and then it is coming like that and then from here this velocity drop will be smaller than this one; this velocity drop will be smaller than this one. Suppose, this much, say v 3 square by twice g and that way we are getting, say this may be even rising here like that and then finally, we can draw this line after this point. And so this way, we are getting the hydraulic gradient line or hydraulic grade line and this is the total energy line.

Well, now, with this understanding we can move on to say, we have discussed about the pipe in series. Now, we can think about, if the pipes are in parallel, then what will happen, that head loss in, in case of pipe in parallel; that we can see.

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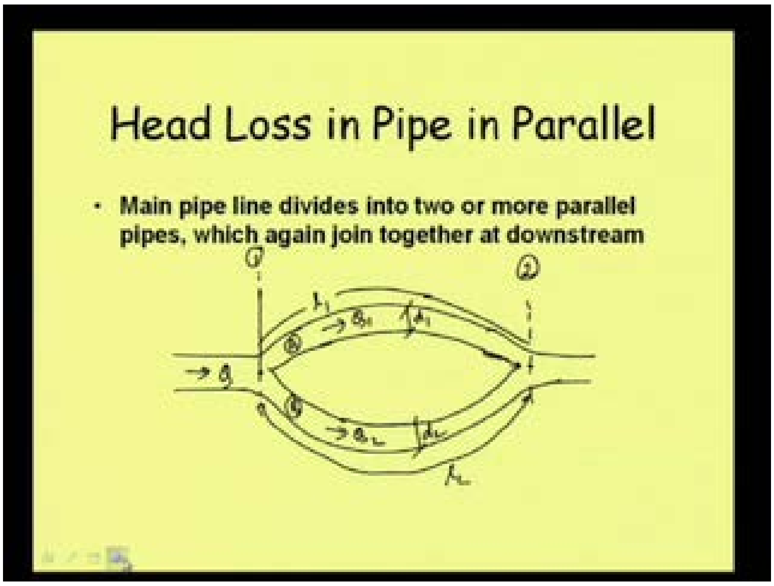

So, main pipelines divide into 2 or more parallel pipe, which again join together at downstream point, so that we can see. Say, this is the pipeline and this is coming like this and then it is going like this and then this joining here. This is one pipe, sorry, this should be uniform from here to here and then, this is the other pipe. Intentionally, I am drawing it in this form, so that the confusion may not be there, that pipe should be, I mean, strictly parallel physically also, it should be parallel, that concept should not be there.

Well, this sort of flow itself we call as flow in parallel pipes, parallel. This is Q 1, this is Q 2, this is Q 2 and let this diameter be d 1 and this diameter be say d 2; diameter be d 2. And here, our concern is that, say this is our point 1 section one and this is our section 2. Well, now, what will be the head loss? The important point is, that say from 0.1 to 0.2 if we go by 1 line, say this length is suppose l 1, this length is l 1, if we go from here to here and if we go from here to here, say this is l 2, then say, from here to here if we are moving, then what will be the head loss through this pipe? And if we move from here to here, what will be the head loss at this pipe? If say, head loss in the pipe 1, suppose this pipe is pipe A, suppose this point, that is, the upper pipe and lower pipe, we are, let, let us say like that, say the pipe A or B, let me name it as pipe A and B. Suppose, in the pipe A we are calculating the head loss and we are finding something head here. So, head at the section 1 minus the head loss through this pipe A, we reach the head, total head at the pipe 2. And then, if we calculate through the pipe B, head loss at pipe A, 0.1 minus the head loss through the pipe B will give us the head at, head at, total available head at 0.2.

But these 2, that is, the head loss through pipe A and head loss through pipe B cannot be different. If they become different, then head loss if we calculate by this root and that root, that is the upper root, upper root and lower root, then the head, total head available at that, at a section 2 will be different, but at a particular section in a pipe there cannot be 2 head existing at a time, head will be practically always one head, we will be getting 1 head available. Well, that, that is why the head loss through the pipe A or through the pipe B should be same and that is the very basic principle of, I mean, doing hydraulics of this particular pipe well.

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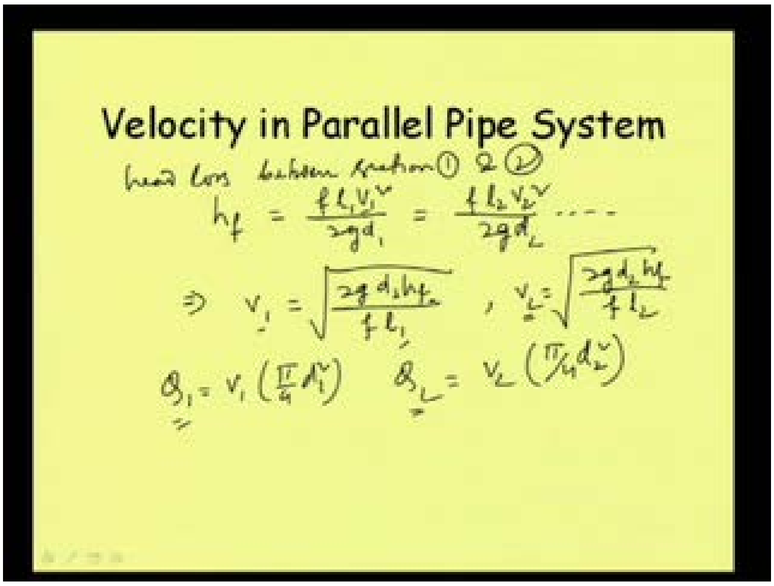

So, we can have, that is, say h f, we can write now here, that h f, that is the head loss is equal to, so head loss between section 1 and 2, head loss between section 1 and 2 if we do, then what we can write, that h f is equal to say, f l 1 v 1 square by twice g d 1, then this is must be equal to f l 2 v 2 square by twice g d 2.

Well, and of course, if there are several pipes there, it is not necessarily, that there will have to be only 2 pipes, there may be several pipes and that is why, say we are putting some dot line here. Well, from that what we can have, from that what we can have, that if we want to know how much discharge will be flowing through one of the pipe, then we first need to know, what is that, I mean, v 1 value. Well, this expression of course, we can, now we do not know exactly how much is the Q flowing. So, we can have this in this form, that v 1 is equal to, this implies, that v 1 is equal to twice g d 1 h f; twice g d 1 h f. And then, f l 1 and then v 1 is equal to root over these things. Similarly, we can calculate v 2 is equal to root over, say twice g d 2 h f divided by f l 2.

So, considering the length of the pipe, diameter of the pipe and having this h f, that is, the head loss, which is equal in both the section, that way we can now find out, what is the v 1 and v 2. If we know the v 1 and v 2, then we can find out, what is the discharge flowing. Say, Q 1 is equal to say v 1 into pi by 4 d square and Q 2 is equal to v 2 into say, pi by 4 d; sorry, this is d 1 square, this is d 2 square.

Well, once we have this v 1 and v 2, like that we can find out what is Q 1 and Q 2. Now, if we want to proportion, if we want to have a, if we want have some proportion of this Q 1 and Q 2, then changing this diameter, suppose we are interested to carry some particular amount of discharge to do this one and particular amount of discharge to this one, then we can proportion our diameter accordingly in a way, that discharge can be distributed accordingly. So, we can adjust these things and we can have, what should be the discharge here and discharge here.

So, this is what the very basic of the parallel pipe and this concept, of course we can use for another objective also, that we can see that flow through a bye-pass.

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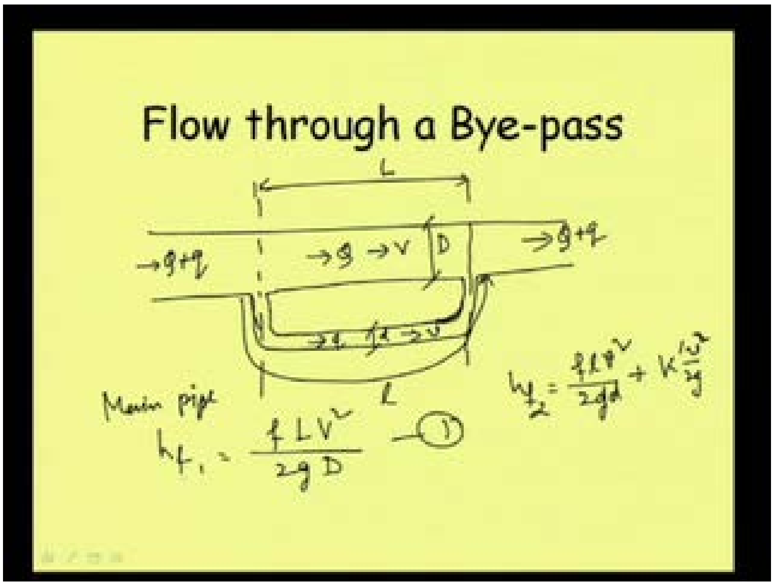

So, this is of course, a phenomenon or a rather this is a concept, that many a time we use bye-pass. Say, this is 1 main pipe and from the main pipe we have a very smaller pipe connecting the main pipe, a very smaller pipe connecting the main pipe, and this pipe is used many a times for measuring discharge. There may be a discharge measuring device as said, that we can fix here and we were interested to find out the discharge. So, suppose, the discharge flowing, our interest is to find out the things between these 2 sections.

Well, say Q is the discharge flowing through this one and V is the velocity, this one, and the diameter, this one, is let me write it capital D and this is the small q, this is small d and the velocity also let me write small v. And then, what we can have, that there is a, it is like the, this is a main pipe and there will be some loss at the entry and there will be some loss at the exit at this point; it is not, that equally it is getting divided or it is going like that, just like the parallel pipe we had, but the head loss between this point and that point should be same; this, this, this point and that point should be same. So, this length I can put as L, this length, and this length I can write, that this total length is say l smaller length is l, then what we can have, that h f for the main pipe. And of course, it is understood, that when this Q and q is coming here, so total discharge is capital Q plus small q here and inside what it is coming, it is also capital Q plus small q, well we can have this one.

So, h f 1 is equal to say f L V square by twice g D, this is say equation 1. And h f 2, that is what is happening in the smaller pipe, say h f 2, that is equal to f L v square, small v square, divided by twice g d and along with that, we will be having some loss, say k dash into v square by twice g, which is a minor loss we are having.

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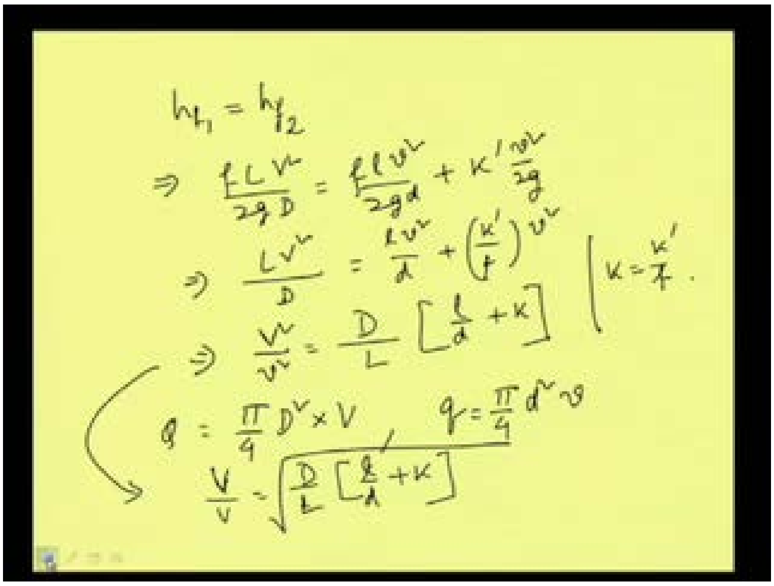

And this we can write in the form, yeah, as h f 1 will have to be equal to h f 2, what we can write that h f 1 equal to h f 2. So, sorry, 2, that implies, that f L V square by twice g D is equal to f l small v square by twice g d plus k dash into v square by twice g. And this implies, say L V square by D that we can write, this is equal to l v square by d twice g and this we are cancelling here. So, v square we can write, here also it is as v square, but here the terms coming will be K dash by f into v square, k dash by f into v square because f was not there in this part and this here we are not having the other terms. So, L V square remaining only, twice g twice g getting cancelled and we can write it like that, from that what we can write? That is, say V square by small v square, this can be written as D by L into L D plus k of course, this K value what we are writing, K is nothing but equal to K dash by f, well. So, we can write this expression.

Well, utilizing this relation well. So, this particular ratio, that is, v square, that means, velocity of the main pipe divided by the velocity of the smaller pipe, this ratio we can use for finding the ratio of the discharge. Because if we see, that say, Q is equal to pi by 4, then capital D square, this is the area, pi by 4 D square area into the velocity and small q, what is actually flowing through the small pipe, this is equal to pi by 4, then small d square pi by 4 d square, that is the area basically and the smaller v, well.

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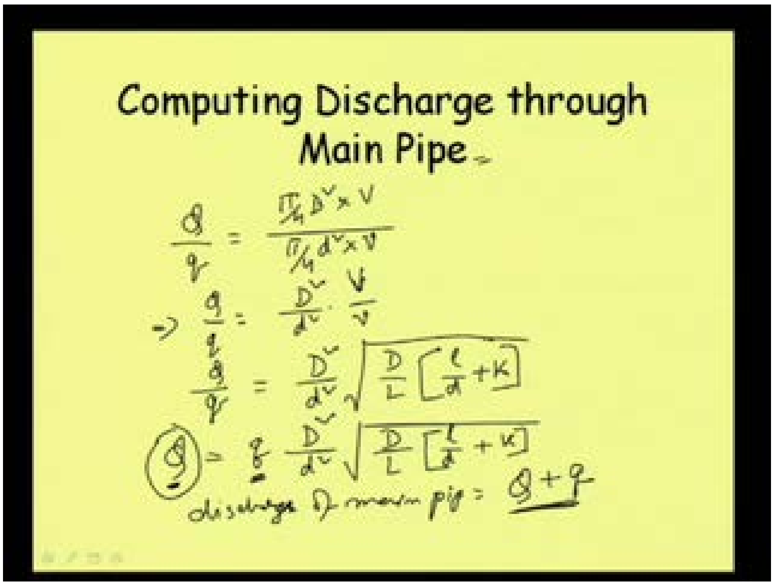

So, Q by q if we write what it will give us? So, discharge through the main pipe if we want to calculate, so we are writing, say Q by small q, we have already the expression for that. So, pi by 4 D square into v divided by pi by 4 D square into small v, well. So, this will give us, that Q by q is equal to D square by d square, small d square, into V by small v, capital V by small v and this capital V by small v, this ratio we have already, earlier we had this v square by v ratio. So, V by v will be equal to root over of this particular expression, we can have that V by v is equal to D by L root over, say D by L into l by d plus k. Well, so this we can utilize now.

Well, so in place of V by v we will be writing this part, so this is equal to D square by d square into root over, we can write, that D by L into l by d plus k. Well, so, that expression is giving us the value of Q by q and as we were discussing now, so q can be calculated as the discharge of the smaller pipe, that is a bye-pass into D square by d square, capital D by small d square. Then pipe, main pipe diameter by main pipe length, then smaller pipe length by smaller pipe diameter plus k, the bye-pass.

So, that means, as we were discussing, if suppose discharge measurement of the main pipe is difficult because of its bigger dimension, so we can measure the discharge of the smaller pipe and then, we can measure or we can calculate the discharge of the bigger pipe or main pipe in the form of this one. So, once q is known other things are already known, so small q we are measuring. So, we can know the capital Q. So, main discharge of the main pipe will be discharge of main pipe, we can have this is equal to Q plus small q as we did indicate here, discharge of the main pipe is equal to Q plus small q here or here, whatever, it is in this proportion only, it is change. Well, like that we can calculate the discharge of the pipe.

So, we have discussed here basically, how we will be adjusting the, how we will be computing the flow and head loss and all those things when the pipes are in series, when the pipes are in parallel and then of course, sometimes as we are repeatedly telling, that this may be a part of the pipe network, a bigger network. Now, if it is a bigger network, how we will be solving that problem in a pipe network, that is also important and that we will be discussing in our next class.

Thank you very much.